Internetworking II, Virtual Circuits

Sections 3.1.2 and 3.3 in the textbook

Slides from Mike Katchabaw

Virtual circuits

- Aim to get circuit-like behaviour over packet-switched networks
- We need small (typically fixed-length) packets
- We need something at the link and/or network layer to handle the virtual circuits

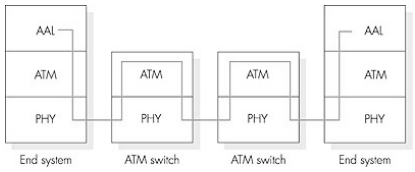
ATM ~~and MPLS~~

- ATM, ~~MPLS~~ separate networks in their own right
  - different service models, addressing, routing from Internet
- viewed by Internet as logical link connecting IP routers
  - just like dialup link is really part of separate network (telephone network)
- ATM, ~~MPLS~~: of technical interest in their own right

Asynchronous Transfer Mode: ATM

- 1990's/00 standard for high-speed (155Mbps to 622 Mbps and higher) *Broadband Integrated Service Digital Network* architecture
- Goal: *integrated, end-end transport of carry voice, video, data*
  - meeting timing/QoS requirements of voice, video (versus Internet best-effort model)
  - "next generation" telephony: technical roots in telephone world
  - packet-switching (fixed length packets, called "cells") using virtual circuits

ATM architecture

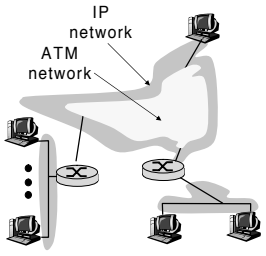


- adaptation layer: only at edge of ATM network
  - data segmentation/reassembly
  - roughly analagous to Internet transport layer
- ATM layer: "network" layer
  - cell switching, routing
- physical layer

ATM: network or link layer?

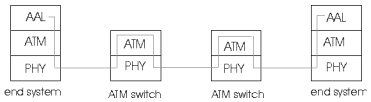
Vision: end-to-end transport: "ATM from desktop to desktop"
- ATM *is* a network technology

Reality: used to connect IP backbone routers
- "IP over ATM"
- ATM as switched link layer, connecting IP routers



ATM Adaptation Layer (AAL)

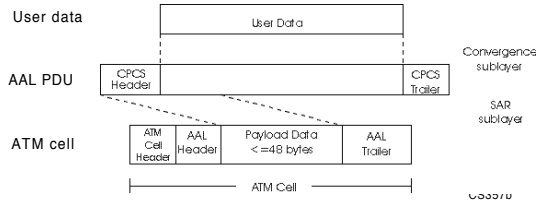
- ATM Adaptation Layer (AAL): "adapts" upper layers (IP or native ATM applications) to ATM layer below
- AAL present only in end systems, not in switches
- AAL layer segment (header/trailer fields, data) fragmented across multiple ATM cells
  - analogy: TCP segment in many IP packets



ATM Adaptation Layer (AAL) [more]

Different versions of AAL layers, depending on ATM service class:

- AAL1: for CBR (Constant Bit Rate) services, e.g. circuit emulation
- AAL2: for VBR (Variable Bit Rate) services, e.g., MPEG video
- AAL5: for data (eg, IP datagrams)



ATM Layer

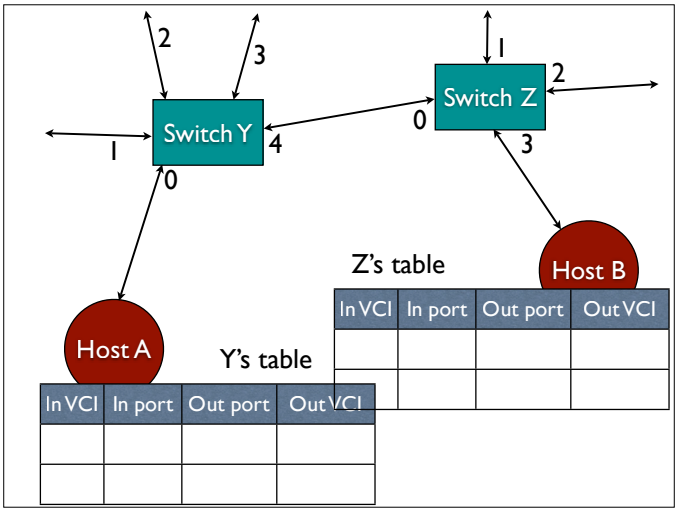
Service: transport cells across ATM network

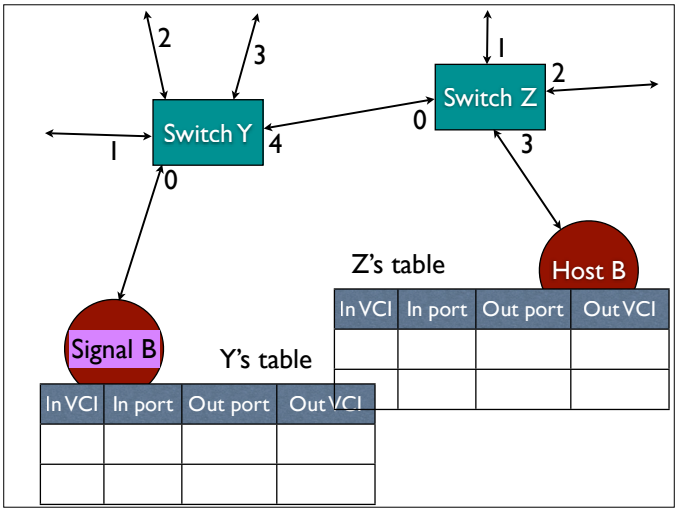
- analogous to IP network layer
- very different services than IP network layer

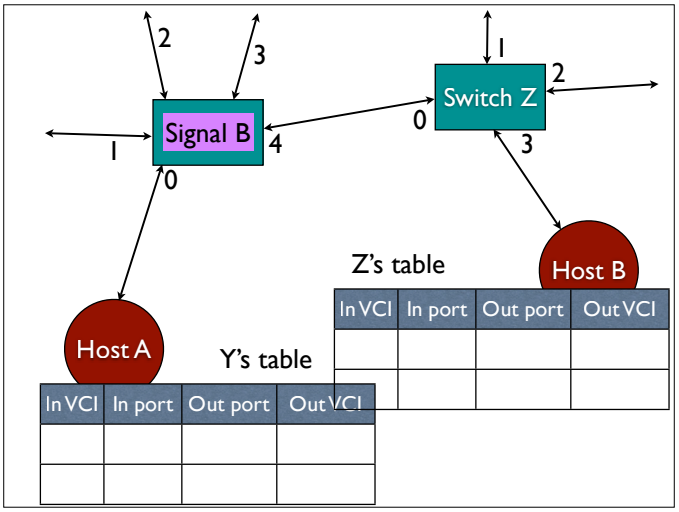
Network Architecture	Service Model	Guarantees ? Bandwidth	Loss	Order	Timing	Congestion feedback
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

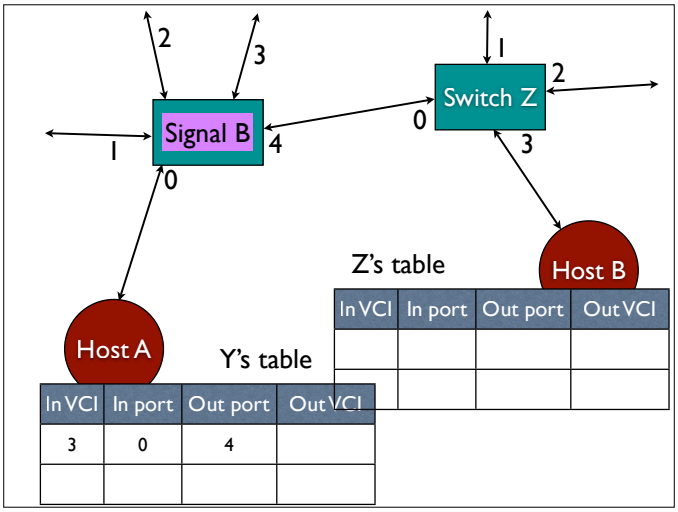
ATM Layer: Virtual Circuits

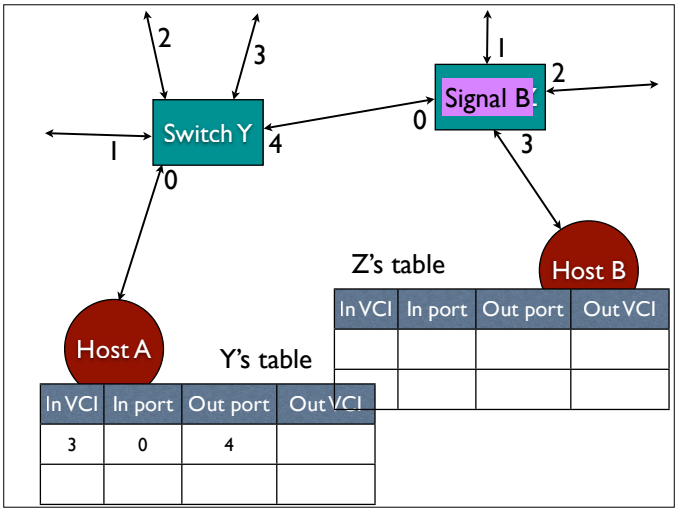
- VC transport: cells carried on VC from source to dest
  - call setup, teardown for each call *before* data can flow
  - each packet carries VC identifier (not destination ID)
  - *every* switch on source-dest path maintain "state" for each passing connection
  - link,switch resources (bandwidth, buffers) may be *allocated* to VC: to get circuit-like perf.
- Permanent VCs (PVCs)
  - long lasting connections
  - typically: "permanent" route between to IP routers
- Switched VCs (SVC):
  - dynamically set up on per-call basis

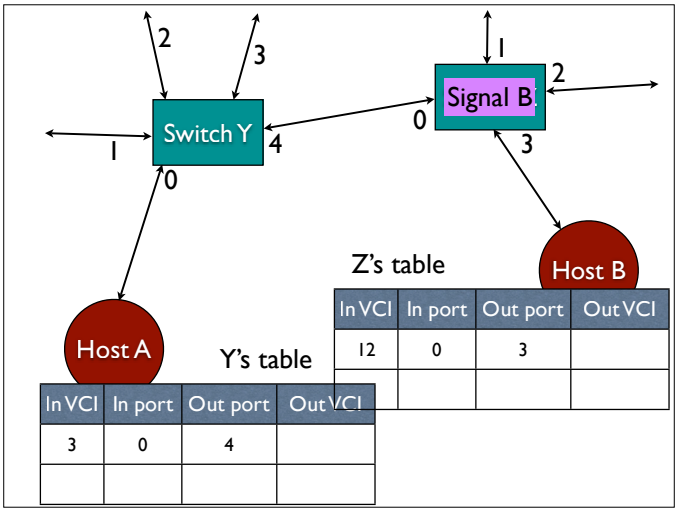


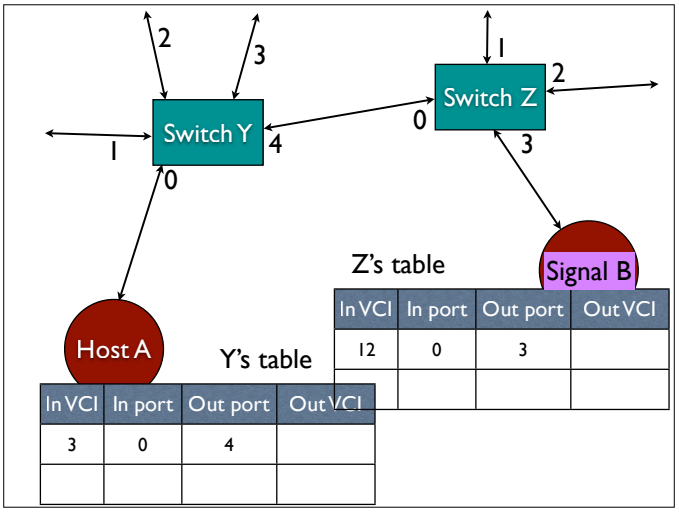


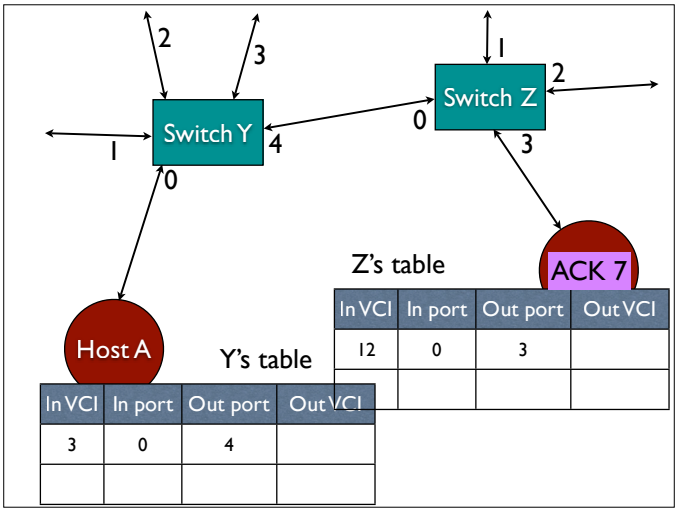

Signal B
Switch Z
Host A
Host B
Y's table
Z's table
In VCI
In port
Out port
Out VCI

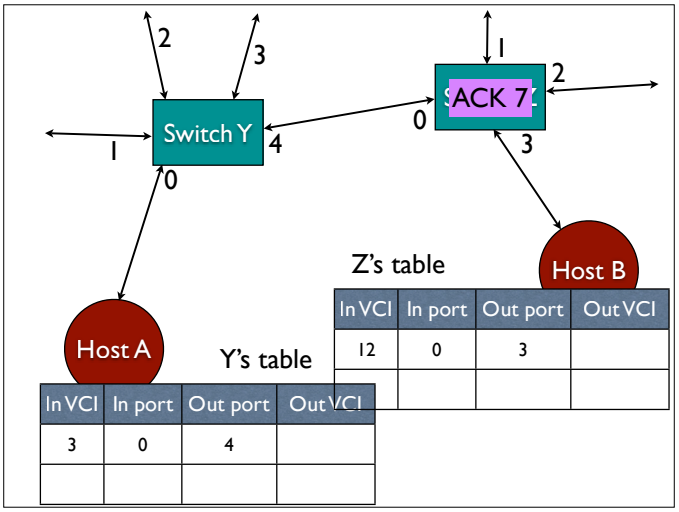

Signal B
Switch Z
Host A
Host B
Y's table
Z's table
In VCI
In port
Out port
Out VCI
3
0
4

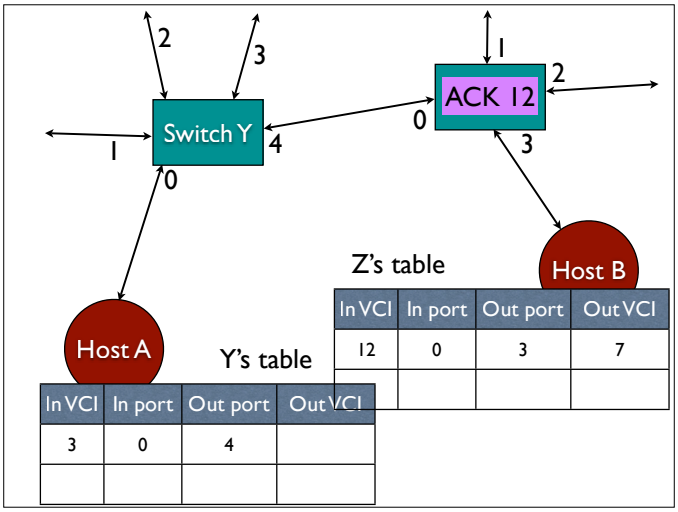

Switch Y
Signal B
Host A
Host B
Y's table
Z's table
In VCI
In port
Out port
Out VCI
3
0
4

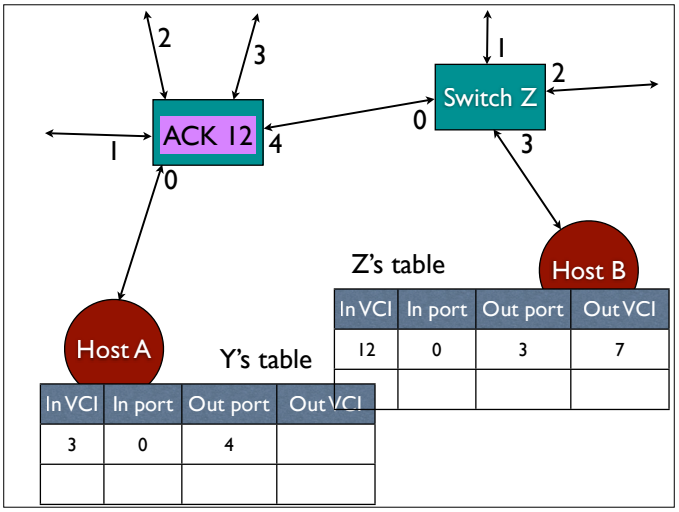

Switch Y
Signal B
Host A
Host B
Y's table
Z's table
In VCI
In port
Out port
Out VCI
12
0
3
3
0
4

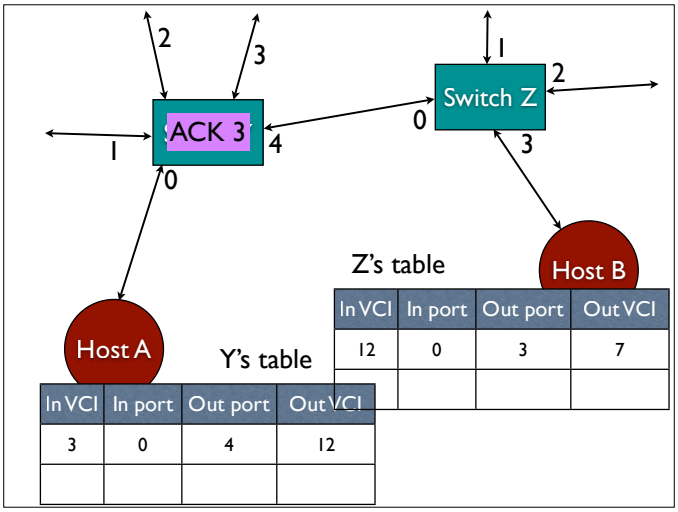

Switch Y
Switch Z
Host A
Signal B
Y's table
Z's table
In VCI
In port
Out port
Out VCI
12
0
3
3
0
4

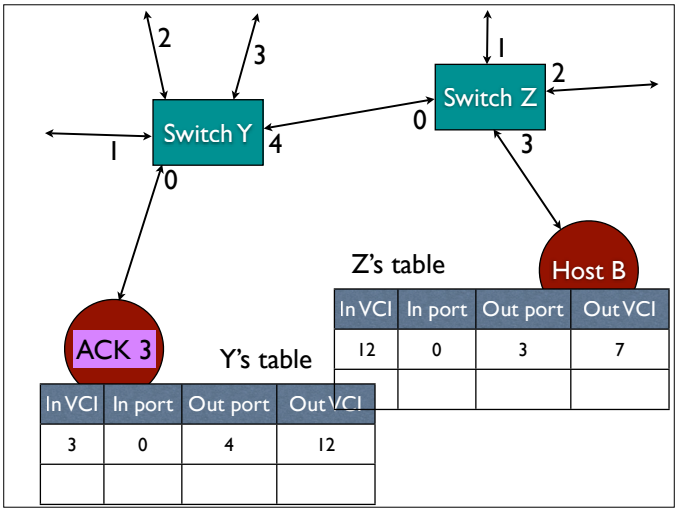

Switch Y
Switch Z
Host A
ACK 7
Y's table
Z's table
In VCI
In port
Out port
Out VCI
12
0
3
3
0
4

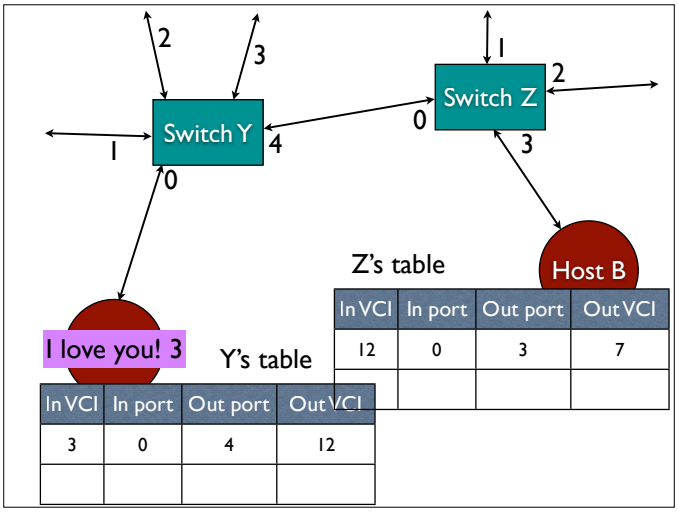

2
3
1
Switch Y
ACK 7
2
1
0
4
0
3
Host A
Host B
Y's table
Z's table
In VCI | In port | Out port | Out VCI
12 | 0 | 3 |
In VCI | In port | Out port | Out VCI
3 | 0 | 4 |

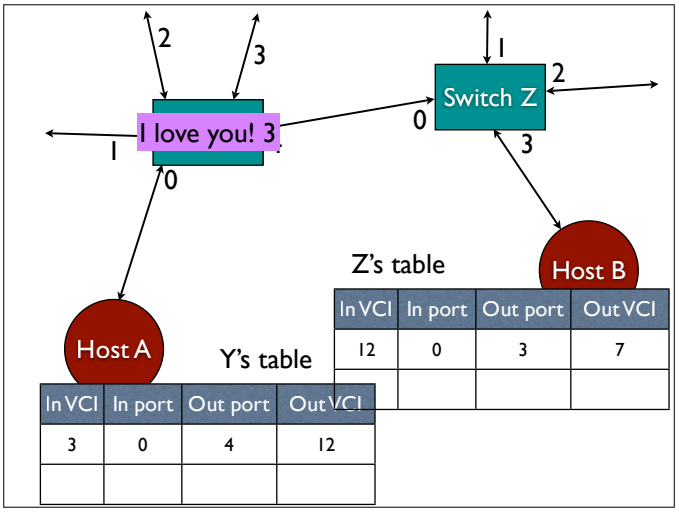

2
3
1
Switch Y
ACK 12
2
1
0
4
0
3
Host A
Host B
Y's table
Z's table
In VCI | In port | Out port | Out VCI
12 | 0 | 3 | 7
In VCI | In port | Out port | Out VCI
3 | 0 | 4 |

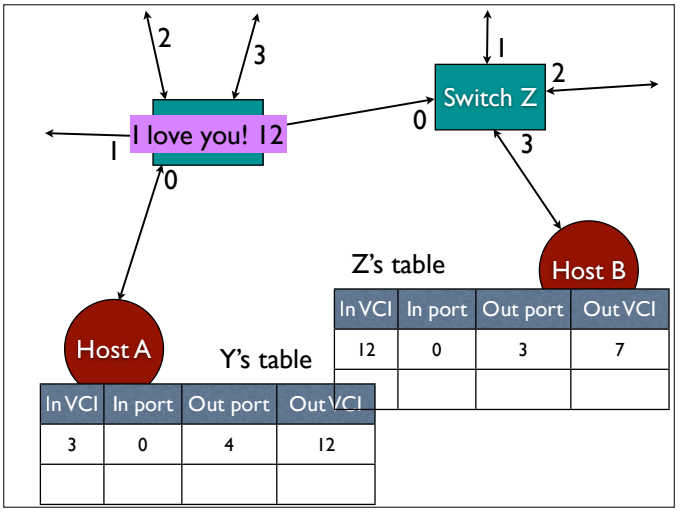

2
3
1
ACK 12
Switch Z
2
1
0
4
0
3
Host A
Host B
Y's table
Z's table
In VCI | In port | Out port | Out VCI
12 | 0 | 3 | 7
In VCI | In port | Out port | Out VCI
3 | 0 | 4 |

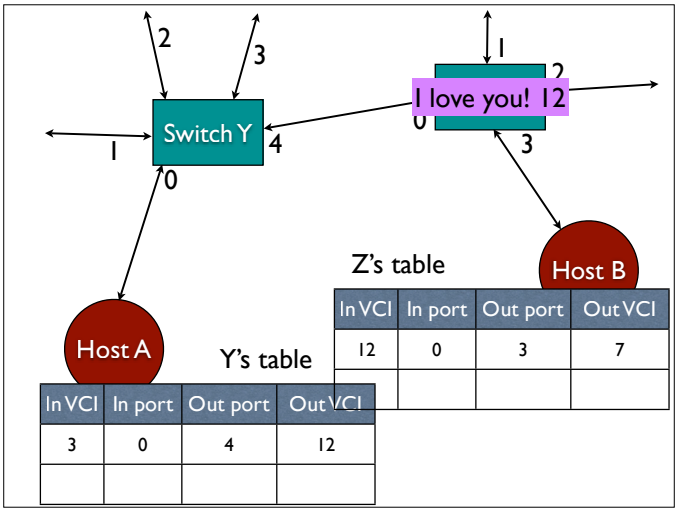

2
3
1
ACK 3
Switch Z
2
1
0
4
0
3
Host A
Host B
Y's table
Z's table
In VCI | In port | Out port | Out VCI
12 | 0 | 3 | 7
In VCI | In port | Out port | Out VCI
3 | 0 | 4 | 12

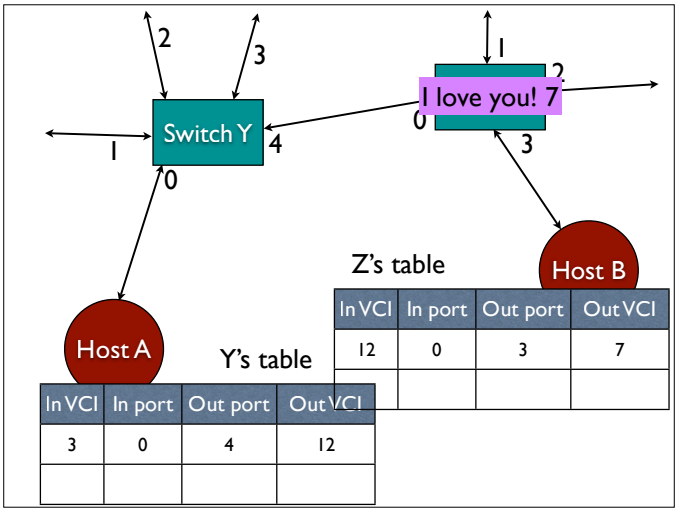

2
3
1
Switch Y
Switch Z
2
1
0
4
0
3
ACK 3
Host B
Y's table
Z's table
In VCI | In port | Out port | Out VCI
12 | 0 | 3 | 7
In VCI | In port | Out port | Out VCI
3 | 0 | 4 | 12

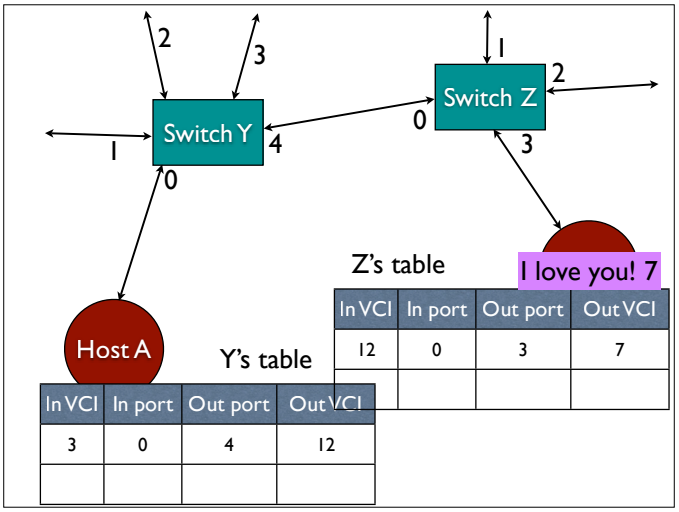

2
3
1
Switch Y
Switch Z
2
1
0
4
0
3
I love you! 3
Host B
Y's table
Z's table
In VCI | In port | Out port | Out VCI
12 | 0 | 3 | 7
In VCI | In port | Out port | Out VCI
3 | 0 | 4 | 12











Addressing properties

- Addresses are only used for connection set-up ("signalling")
- Virtual Circuit Identifiers (VCIs) are used for sending messages and for "teardown"
- This doesn't scale! Every connection needs an entry in every switch along the way!
  - Or does it?

VPIs and VCIs

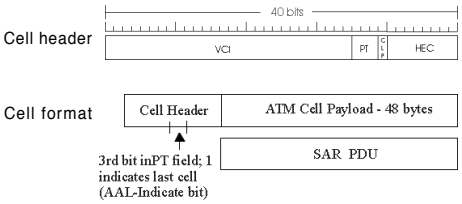
- ATM cells have a 24-bit VCI which can be broken down into:
  - 8-bit VPI (Virtual Path Identifier)
  - 16-bit VCI
- Higher-level "backbone" routers only pay attention to VPIs and completely ignore VCIs

ATM VCs

- Advantages of ATM VC approach:
  - QoS performance guarantee for connection mapped to VC (bandwidth, delay, delay jitter)
- Drawbacks of ATM VC approach:
  - Inefficient support of datagram traffic
  - one PVC between each source/dest pair) does not scale (N*2 connections needed)
  - SVC introduces call setup latency, processing overhead for short lived connections

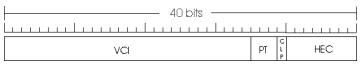
ATM Layer: ATM cell

- 5-byte ATM cell header
- 48-byte payload
  - Why?: small payload -> short cell-creation delay for digitized voice
  - halfway between 32 and 64 (compromise!)



ATM cell header

- VCI: virtual channel ID
  - will *change* from link to link thru net
- PT: Payload type (e.g. RM cell versus data cell)
- CLP: Cell Loss Priority bit
  - CLP = 1 implies low priority cell, can be discarded if congestion
- HEC: Header Error Checksum
  - cyclic redundancy check



ATM Physical Layer

Physical Medium Dependent (PMD) sublayer

- SONET/SDH: transmission frame structure (like a container carrying bits);
  - bit synchronization;
  - bandwidth partitions (TDM);
  - several speeds: OC3 = 155.52 Mbps; OC12 = 622.08 Mbps; OC48 = 2.45 Gbps, OC192 = 9.6 Gbps
- T1/T3: transmission frame structure (old telephone hierarchy): 1.5 Mbps/ 45 Mbps
- unstructured: just cells (busy/idle)

Midterm exam

- Next Wednesday (in class time)
- Review session on Monday!
  - No notes or MP3 online for Monday
- Covers everything up to today (chapters 1 to 3 in the textbook, plus 7.2, plus error correction that wasn't in the textbook)

Midterm

- Roughly 20%–30% of the marks will be "regurgitation"
  - The review session on Monday won't help much here.
- Mostly multiple choice
  - T/F: CRC always detects 1-bit errors?
- Some short answer:
  - Describe how an Ethernet device aborts sending a frame if it detects a collision.

Midterm

- Roughly 50%–70% will be "do it" questions
  - Some multiple choice!
  - The review session will help here!
- On the exam: calculate CRC, do Lempel-Ziv
- Not on the exam: construct a generator matrix from a check matrix for linear codes

Midterm

- Roughly 10% will be "thinking" questions
- While you study, ask yourself "why?" and "what if?" a lot
- Applications to areas outside of networking