Data Communications & Networks

Session 3 – Main Theme
Data Encoding and Transmission

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Agenda

1 **Session Overview**

2 **Data Encoding and Transmission**

3 **Summary and Conclusion**

What is the class about?

- Course description and syllabus:
  - » http://www.nyu.edu/classes/jcf/g22.2262-001/
  - » http://www.cs.nyu.edu/courses/spring10/G22.2262-001/index.html

- Textbooks:
  - » ***Computer Networking: A Top-Down Approach (5th Edition)***

James F. Kurose, Keith W. Ross
Addison Wesley
ISBN-10: 0136079679, ISBN-13: 978-0136079675, 5th Edition (03/09)

Course Overview

- Computer Networks and the Internet
- Application Layer
- Fundamental Data Structures: queues, ring buffers, finite state machines
- Data Encoding and Transmission
- Local Area Networks and Data Link Control
- Wireless Communications
- Packet Switching
- OSI and Internet Protocol Architecture
- Congestion Control and Flow Control Methods
- Internet Protocols (IP, ARP, UDP, TCP)
- Network (packet) Routing Algorithms (OSPF, Distance Vector)
- IP Multicast
- Sockets

Data Transmission and Encoding Session in Brief

- Data Transmission and Encoding Concepts
- ADTs and Protocol Design
- Summary and Conclusion

Icons / Metaphors

 Information

 Common Realization

 Knowledge/Competency Pattern

 Governance

 Alignment

 Solution Approach

Agenda

1 Session Overview

2 Data Encoding and Transmission

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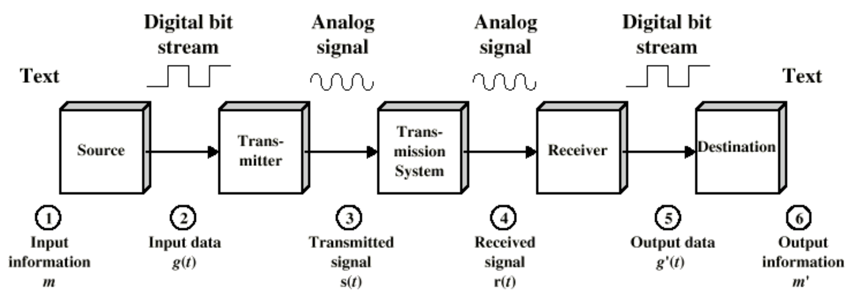
Data Encoding and Transmission - Roadmap

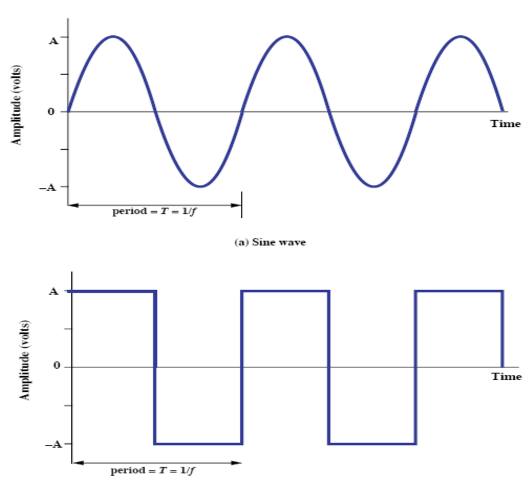
2 Data Encoding and Transmission

- Data Encoding and Transmission Concepts
- ADTs and Protocol Design

Simplified Data Communications Model



S(t) = A sin(2πft + Φ)



(a) Sine wave

(b) Square wave

Terminology (1/3)

- Transmitter
- Receiver
- Medium
  - Guided medium
    - E.g., twisted pair, optical fiber
  - Unguided medium
    - E.g., air, water, vacuum

Terminology (2/3)

- Direct link
  - No intermediate devices
- Point-to-point
  - Direct link
  - Only 2 devices share link
- Multi-point
  - More than two devices share the link

Terminology (3/3)

- Simplex
  - One direction
    - e.g., television
- Half duplex
  - Either direction, but only one way at a time
    - e.g. police radio
- Flux duplex
  - Both directions at the same time
    - e.g., telephone

Analog and Digital Data Transmission

- Data
  - Entities that convey meaning
- Signals
  - Electric or electromagnetic representations of data
- Transmission
  - Communication of data by propagation and processing of signals

Data

- Analog
  - Continuous values within some interval
    - e.g., sound, video
- Digital
  - Discrete values
    - e.g., text, integers

Signals

- Means by which data are propagated
- Analog
  - Continuously variable
  - Various media
    - e.g., wire, fiber optic, space
  - Speech bandwidth 100Hz to 7kHz
  - Telephone bandwidth 300Hz to 3400Hz
  - Video bandwidth 4MHz
- Digital
  - Use two DC components

Data and Signals

- Usually use digital signals for digital data and analog signals for analog data
- Can use analog signal to carry digital data
  - Modem
- Can use digital signal to carry analog data
  - Compact Disc audio

Analog Transmission

- Analog signal transmitted without regard to content
- May be analog or digital data
- Attenuated over distance
- Use amplifiers to boost signal
- Also amplifies noise

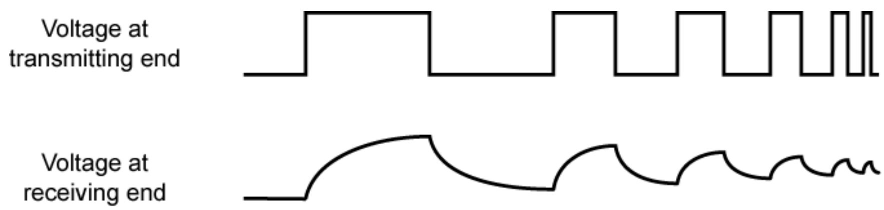
Digital Transmission

- Concerned with content
- Integrity endangered by noise, attenuation etc.
- Repeaters used
- Repeater receives signal
- Extracts bit pattern
- Retransmits
- Attenuation is overcome
- Noise is not amplified

Advantages/Disadvantages of Digital

- Cheaper
- Less susceptible to noise
- Greater attenuation
  - Pulses become rounded and smaller
  - Leads to loss of information

Attenuation of Digital Signals



Interpreting Signals

- Need to know
  - Timing of bits - when they start and end
  - Signal levels
- Factors affecting successful interpreting of signals
  - Signal to noise ratio
  - Data rate
  - Bandwidth

Encoding Schemes

- Non-return to Zero-Level (NRZ-L)
- Non-return to Zero Inverted (NRZI)
- Bipolar –AMI
- Pseudoternary
- Manchester
- Differential Manchester
- B8ZS
- HDB3

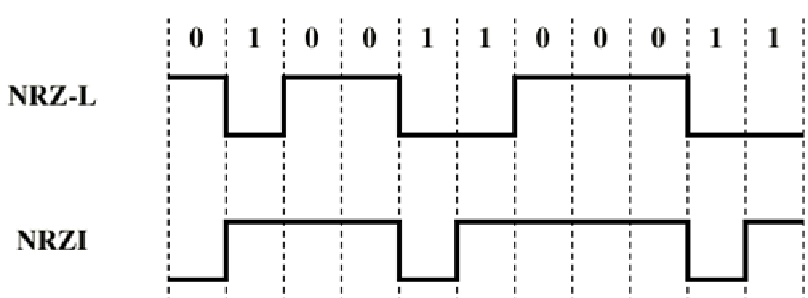
Non-Return to Zero-Level (NRZ-L)

- Two different voltages for 0 and 1 bits
- Voltage constant during bit interval
  - No transition (i.e. no return to zero voltage)
  - e.g., Absence of voltage for zero, constant positive voltage for one
- More often, negative voltage for one value and positive for the other
- This is NRZ-L

Non-Return to Zero Inverted

- Nonreturn to zero inverted on ones
- Constant voltage pulse for duration of bit
- Data encoded as presence or absence of signal transition at beginning of bit time
- Transition (low to high or high to low) denotes a binary 1
- No transition denotes binary 0
- An example of differential encoding

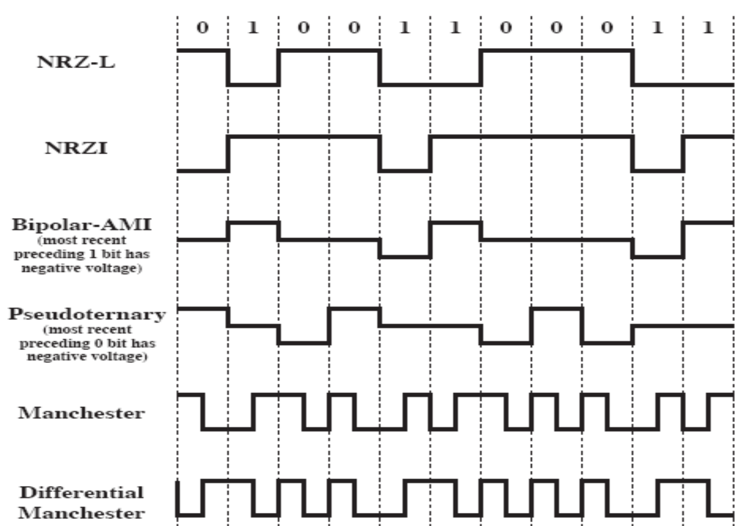
NRZ



Differential Encoding

- Data represented by changes rather than levels
- More reliable detection of transition rather than level
- In complex transmission layouts it is easy to lose sense of polarity

Summary of Encodings



NRZs Pros and Cons

- Pros
  - Easy to engineer
  - Make good use of bandwidth
- Cons
  - DC component
  - Lack of synchronization capability
- Used for magnetic recording
- Not often used for signal transmission

Biphase

- Manchester
  - Transition in middle of each bit period
  - Transition serves as clock and data
  - Low to high represents one
  - High to low represents zero
  - Used by IEEE 802.3
- Differential Manchester
  - Mid-bit transition is clocking only
  - Transition at start of a bit period represents zero
  - No transition at start of a bit period represents one
  - Note: this is a differential encoding scheme
  - Used by IEEE 802.5

Biphase Pros and Cons

- Con
  - At least one transition per bit time and possibly two
  - Maximum modulation rate is twice NRZ
  - Requires more bandwidth
- Pros
  - Synchronization on mid bit transition (self clocking)
  - No dc component
  - Error detection
  - Absence of expected transition

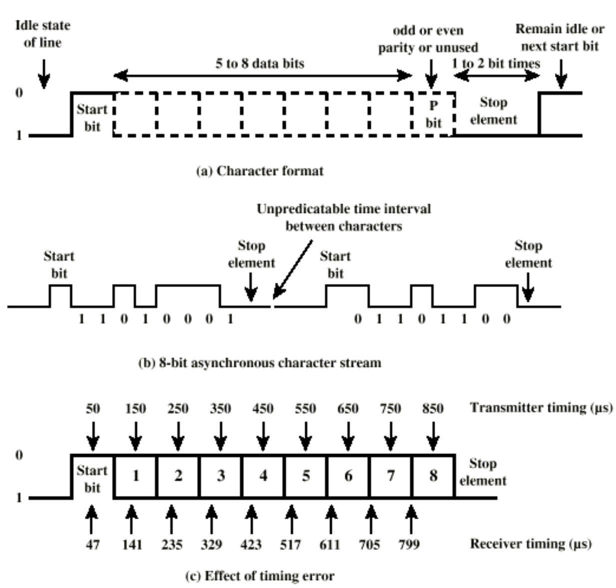
Asynchronous/Synchronous Transmission

- Timing problems require a mechanism to synchronize the transmitter and receiver
- Two solutions
  - Asynchronous
  - Synchronous

Asynchronous

- Data transmitted on character at a time
  - 5 to 8 bits
- Timing only needs maintaining within each character
- Resync with each character

Asynchronous (Diagram)



Asynchronous - Behavior

- In a steady stream, interval between characters is uniform (length of stop element)
- In idle state, receiver looks for transition 1 to 0
- Then samples next seven intervals (char length)
- Then looks for next 1 to 0 for next char
- Simple
- Cheap
- Overhead of 2 or 3 bits per char (~20%)
- Good for data with large gaps (keyboard)

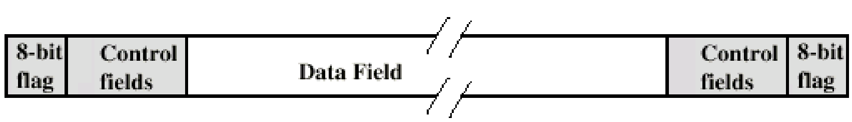
Synchronous – Bit Level

- Block of data transmitted without start or stop bits
- Clocks must be synchronized
- Can use separate clock line
  - Good over short distances
  - Subject to impairments
- Embed clock signal in data
  - Manchester encoding
  - Carrier frequency (analog)

Synchronous – Block Level

- Need to indicate start and end of block
- Use preamble and postamble
  - e.g. series of SYN (hex 16) characters
  - e.g. block of 11111111 patterns ending in 11111110
- More efficient (lower overhead) than async

Synchronous (diagram)



Data Encoding and Transmission - Roadmap

2 **Data Encoding and Transmission**

- Data Encoding and Transmission Concepts
- ADTs and Protocol Design

Common Issues in Design

- When building protocol software, there are two common problems that designers face:

  1) How to handle data that arrives from two independent sources
     - Down from the higher layer
     - Up from the lower layer

  2) How to implement the protocol

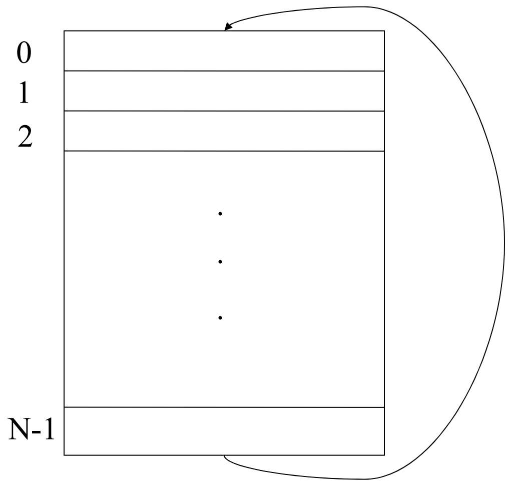
Data from Two Sources

- Down from the Higher Layer (HL)
  - Higher layer (HL) sends requests (control and data)
  - Cannot always process the request immediately, so we need a place to hold the request
  - We may get "many" HL users (e.g., many TCP, only one IP)
  - Requests may need to be processed out of order (out of band, QOS, etc)

Data from Two Sources

- Up from the Lower Layer (LL)
  - Lower layer sends data and indications
  - Data must be separated from indications
  - Read requests from HL may use different data boundaries than LL
  - LL may be providing data at same time as HL wants to read it

Ring Buffer of Size N

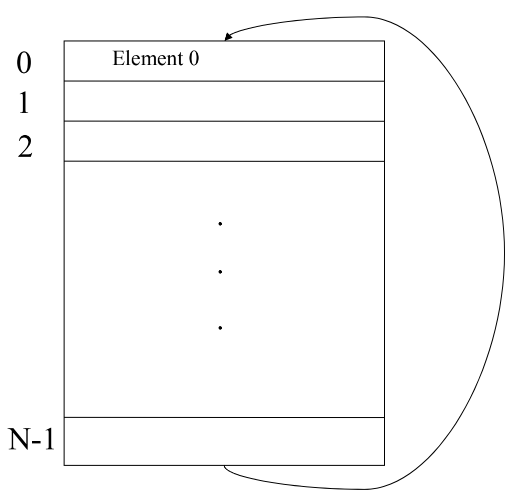


Inititial State

Input: 0

Output: 0

Ring Buffer of Size N

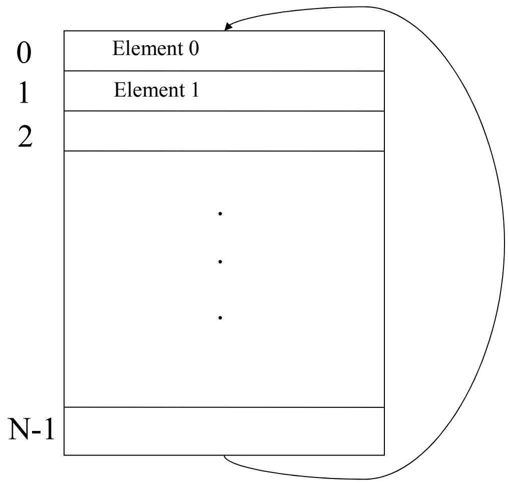


New Element Arrives

Input: 1

Output: 0

Ring Buffer of Size N

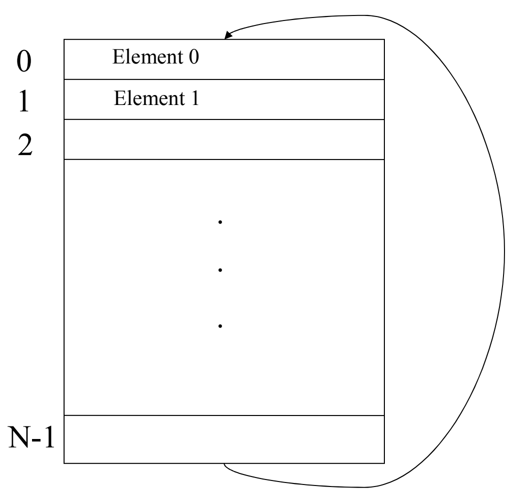


New Element Arrives

Input: 2

Output: 0

Ring Buffer of Size N



Read next (element 0)

Input: 2

Output: 1

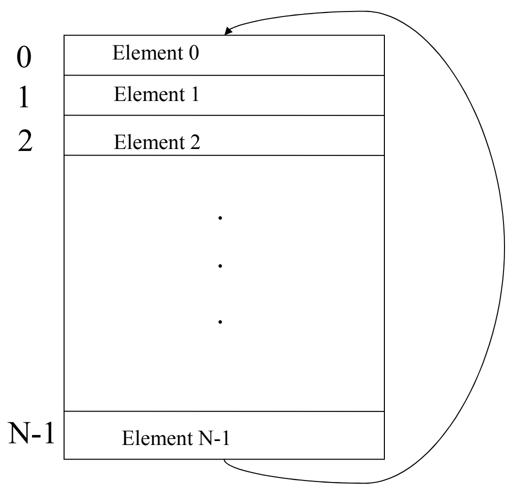
↓

Read next (element 1)

Input: 2

Output: 2

Ring Buffer of Size N



After Nth input:

Input: 0

Output: 2

How many more input elements can we accept?

Ring Buffer Spec (1/3)

Let B be a buffer.

Let S be the size of the buffer B in bytes.

Let I be an index into the buffer where the producer will store the next new byte of data.

Let O be the index of the next byte that the consumer should remove from the buffer.

Let N be the number of unconsumed bytes in the buffer.

Define % as the modulus operator.

Initially, I = O = N = 0.

The buffer is full (has no room for new data) when N == S.

The available space (for new data) A = S - N

Ring Buffer Spec (2/3)

To Add m bytes of data from buffer D to the buffer B the producer will:

(1) Check that m <= A (if not an error has occurred)
(2) put bytes into the buffer using this model:

```
int j = I;
I = (I+m)%S
N += m;

for (int q = 0; q < m; q++)
   B[(j+q)%S] = D[q]
```


Ring Buffer Spec (3/3)

To remove r bytes from the buffer B to buffer D, the consumer will:

(1) Check that r <= N. If not, adjust r (r = N) or signal error.
(2) take bytes from the buffer using this model:

```
int j = O;
O = (O+r)%S
N -= r

for (int q = 0; q < r; q++)
  D[q] = B[(j+q)%S]
```

Ring Buffer: Making it Safe

So, you see that the idea is that the input (I) and output (O) pointers change continuously from the beginning of the buffer to the end and then wrap around back to the beginning again. Conceptually, it appears as if the end of the buffer is connected back the front of the buffer as if to form a ring (or circle). We enforce that the input pointer never tries to overtake the output pointer!

To make these two methods thread safe, we need only to protect the 3 lines of code that update the class variables O, N, I: NOT the loops that move data! This is a better real-time approach than serializing access to the loop itself, or worse, the entire object.

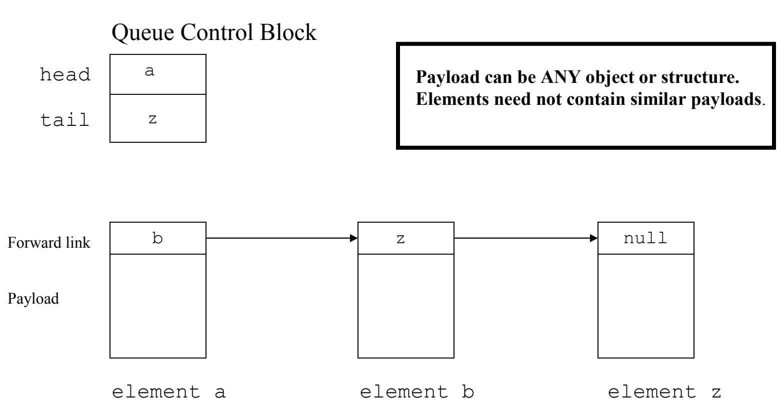
Ring Buffer Characteristics

- Elements are all same size and type
  - Elements are typically primitives (byte, int, etc) but can be pointers or even structures
- Finite
  - Fixed space must be allocated a priori
- Low overhead
  - No “per element” costs like we have in a Queue
- Elements MUST be processed in order.

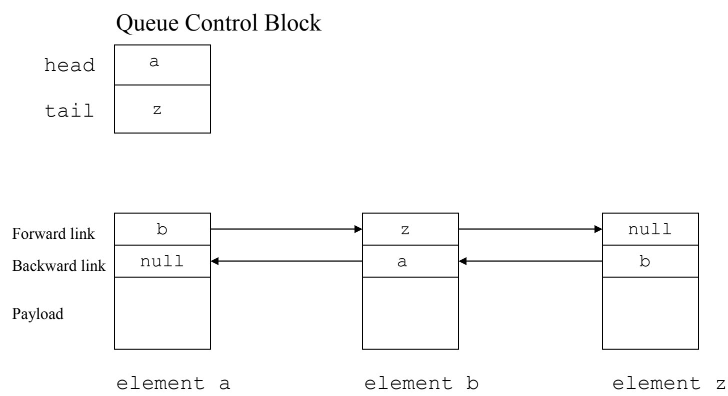
Queue

- Elements are linked together in a list
- List can be single (forward) or double (forward and backward) linked
- Queue Control Block contains (as a minimum) pointer to first element (head) and last element (tail)
- Queues are almost always used as FIFOs, but can support iteration, random access, and reverse (LIFO) processing

Queue (Singly Linked)



Queue (Doubly Linked)



Queue Operations

- Required Operations
  - Put (add to tail)
  - Get (get from head)
- Nice to Have Operations
  - Remove (remove specific element)
  - Insert (add element after a specific element)
- *Deluxe* Operations
  - Peek (non-destructive Get)
  - Put to head
  - Get from tail
  - Iterate (head to tail or tail to head)

Queue Characteristics

- Not fixed in length ("unlimited" in length)
- Does not require pre-allocated memory
- Allows processing of elements in arbitrary order
- Can accommodate elements of different type
- Additional per element cost (links)

Queue or Ring Buffer

- Stream data: Use a ring buffer
  - Arriving elements are primitives that make up a data "stream" (no record boundaries)
    - TCP data is an example
- Service requests: Use a queue
  - Arriving elements are requests from a user layer (or clients) and must be processed individually.

What is a FSM?

- Let's define the idea of a "**machine**"
  - Organism (real or synthetic) that responds to a countable (**finite**) set of stimuli (**events**) by generating predictable responses (**outputs**) based on a history of prior events (current **state**)
- A finite state machine (fsm) is a computational model of a machine

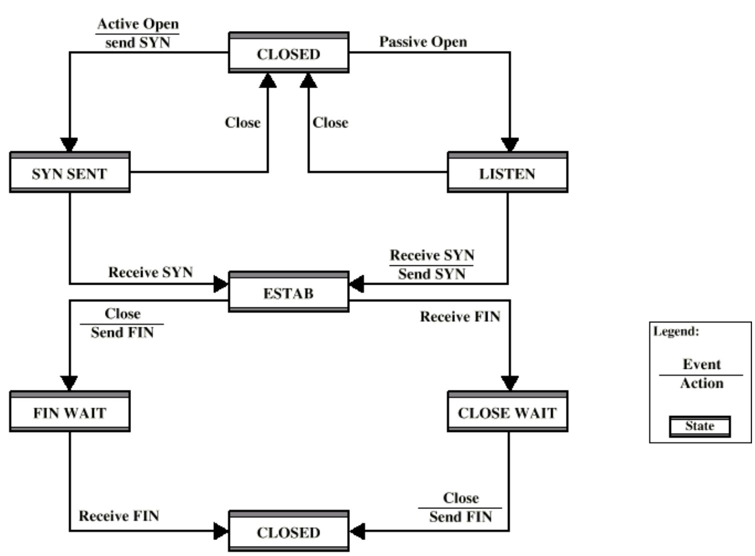
FSM Elements

- **States** represent the particular configurations that our machine can assume
- **Events** define the various inputs that a machine will recognize
- **Transitions** represent a change of state from a current state to another (possibly the same) state that is dependent upon a specific event
- The **Start State** is the state of the machine before is has received any events

Machine Types

- **Mealy** machine
  - one that generates an output for each transition
- **Moore** machine
  - one that generates an output for each state
- Moore machines can do anything a Mealy machine can do (and vice versa)
- In my experience, Mealy machines are more useful for implementing communications protocols
- The fsm that I'll provide is a Mealy machine

State Diagram



From State Diagram to FSM

- Identify
  - *States*
  - *Events*
  - *Transitions*
  - *Actions* (outputs)
- Program these elements into an FSM
- Define an event classification process
- Drive the events through the FSM
- Example ….

Agenda

1. Session Overview
2. Application Layer
3. Summary and Conclusion

Assignments & Readings

- Readings

  » Chapter 1
- Assignment #2

Next Session: Data Link Control