EECS 563 Fall 2021

Review Test 2

Network traffic

- Request for resources
  - Rate of requests = Arrival rate= λ
  - Average resource hold time = T_h
  - For statistical multiplexer:
    T_h=packet length(bits)/link rate (bits/sec)=L/R
  - Common Assumptions
    - Time between arrivals ~ exponentially distributed
    - Holding time ~ exponentially distributed
- Load
  - λ = packet/sec or calls/sec or files/sec…
  - T_h= average holding time sec/call
    - Service rate $\mu=1/T_h$
  - Load $=\rho = \lambda * T_h$ Erlangs$=\lambda/\mu$
    - Statistical multiplexer: $\rho = \lambda *$(packet length)/link rate

Network traffic

- Packet Voice
  - Constraint→ limit on end-to-end delay
  - Packetization time (ms/packet)
  - Role of the Jitter buffer
    - Compensate for random network delays
    - Jitter buffer size in bytes (or bits) or ms
    - Too small → lose packets
    - Too large → increase delay

Network traffic

- Packet Voice
  - Components of end-to-end delay (delay budget) & trade-offs
    - Packetization time
    - Clocking time
    - Network delay (random)
    - Jitter buffer
  - VoIP Rate calculation
- Data
  - Burstyness = (Peak rate)/(Average rate)
  - Large Burstyness leads to effective statistical multiplexing.

Performance Analysis

- Given
  - Traffic
  - QoS
- Design system
  - For M/M/1 → Find R
  - For M/M/1/K → Find R and/or System size=K
  - For For M/M/K/K → Find Number of Servers
    - Assumptions
      - Service time ~ Exponentially distributed
      - Interarrival time ~ Exponentially distributed

M/M/1

Probability of k in system=P[K=k] = $\rho^k(1-\rho)$
Probability of system busy = utilization= ρ
Probability of system empty = 1-ρ

$$Average\ Number\ in\ System = E[K] = \frac{\rho}{1-\rho}$$

$$\text{Variance of } Number\ in\ System = \mathrm{Var}[K] = \frac{\rho}{(1-\rho)^2}$$

← Given on Test

$$Delay\ through\ System = E[D] =$$

$$E[D] = \frac{1}{\mu(1-\rho)} = \frac{\frac{E[L]}{R_{out}}}{(1-\rho)} = \frac{E[Holding\ time]}{(1-\rho)} = \frac{1}{\mu-\lambda}$$

M/M/1/K and M/M/K/K

- M/M/1/K

$$P_{Blocking} = P[K = S] = \frac{(1-\rho)\rho^S}{1-\rho^{S+1}}$$

← Given on Test

Blocking Probability in % for an M/M/1/K System

Load =	0.2	0.3	0.40	0.5	0.6	0.7	0.8
K	Probability of Blocking (%)	Probability of Blocking (%)	Probability of Blocking (%)	Probability of Blocking (%)	Probability of Blocking (%)	Probability of Blocking (%)	Probability of Blocking (%)
1	16.6667	23.0769	28.5714	33.3333	37.5000	41.1765	44.4444
2	3.2258	6.4748	10.2564	14.2857	18.3673	22.3744	26.2295

← Full Table Given on Test

- M/M/K/K → Erlang B ← Table Given on Test

MAC

- Scaling & trade-offs WRT:
  - rate (b/s),
  - number of users, and
  - size (km)
- Deterministic (Polling)
  - Operation (why called deterministic)
  - Calculate effective rate & efficiency

MAC

- Random Access
  - Collision process
    - Time vulnerable to collision

      Time vulnerable to collision ↑ then S_{max} ↓
    - Detecting Collisions
  - Time
    - Unslotted
    - Slotted
  - Role of backoff process

MAC (Random Access-continued)

- Types (all can be slotted/unslotted)
  - ALOHA (for unslotted S_{max}=18%, for slotted S_{max}= 36%)
    - Vulnerable to collision ~L/R sec (not function of τ)
  - CSMA
    - Vulnerable to collision ~τ sec
    - p-persistent (1-persistent)
    - Non-persistent
    - CSMA/CD

$$a = \frac{\tau}{\frac{L}{R}} \text{ where } \tau = \text{End-to-End Propagation Time}$$

$$\text{As } a \uparrow \quad S_{Max} \downarrow \text{ and as } a \rightarrow 1,\ S_{Max} \rightarrow ALOHA$$

- Leads to specification of Min/Max Packet size

MAC

- Collision Free Protocols
- Centralized Reservation Systems
  - In upstream - send requests to transmit
    - Use part of cycle time (contention slots) to send requests
    - Use random access to share contention slots
  - Receive grants to transmitt in the downstream
  - No contention in downstream
  - If no grant in downstream then assume collision for the request, backoff and resend request in upstream
  - Vulnerable to collision ~cycle time

MAC

Maximum Throughput for Centralized Reservation Systems
(No contention for reservation slots)

$$S_{\max} = \frac{1}{1 + \frac{v}{Xk}}$$

R = Link rate (b/s)
L = packet size (bits) assume fixed length
v= minislot size (sec)
M = Number of stations
X = L/R (sec) = clocking time
k = number of packet transmissions reserved with ONE reservation message

Maximum Throughput for Centralized Reservation Systems
(Using Aloha for access to reservation slots)

$$S_{\max} = \frac{1}{1 + \frac{2.7v}{X}}$$

Ethernet

- IEEE 802.3
  - Evolution
    - Bus
    - Hub
    - Switch
    - 10 Mb/s → 100 Gb/s
  - Role of CSMA/CD

Network Elements

- Repeater
- Bridge
- Switch
- Router
  - Layer 2 Switch
  - Layer 3 Switch
  - Layer 4 Switch
  - Layer "Any" Switch

Wireless Networks

- Issues
  - Noise
  - Signal Fading
  - Hidden terminal
- RTS/CTS

Cable Networks

- DOCSIS
- Access protocol
  - Centralized Reservation Systems
- CM, Headend, CMTS

DLC

- Goal→ point-to-point error free link
- Functions
  - Framing→ Flags & bit stuffing
  - Error recovery
  - Flow control

DLC

- Sliding window flow control
  - n bits/SN in packet header
  - Max window →$N= 2^n-1$
  - N=1 → Stop and Wait
  - When to retransmit?
    - Timeout
    - RNR (NACK)
  - What to retransmit?
    - Uses SN
    - Go-back-N
    - Selective Repeat

DLC

- Piggybacking
- Frame structure
    - Components of the packet overhead
- HDLC

DLC

- Performance

$$\eta = \frac{R_{eff}}{R}$$

$$R_{eff} = \frac{\#\,bits}{\text{Time to tx}\ \#\,bits}$$

* Understand assumptions behind these equations

- Stop&Wait*

N_{RTT} = # Frames in RTT

$$\eta_{stop\,\&wait} = \frac{1}{1+\frac{2\tau R}{n_f}} \quad \boxed{= \frac{1}{1+N_{RTT}}}$$

- Sliding window*

$$\eta_{Sliding\,Window} = \begin{cases} 1 \text{ if N} \geq \frac{2\tau R}{n_f}+1 \\ \frac{N}{1+\frac{2\tau R}{n_f}} \text{ if } N < \frac{2\tau R}{n_f}+1 \end{cases}$$

Small Window Case

$$\boxed{\frac{N}{1+N_{RTT}}}$$

DLC

- Control the source rate by limiting the window size
- Open Loop Control
  - DE bit
  - Methods
    - CIR, B_c, B_e
    - Token bucket
      - Average rate
      - Maximum burst size

Transport Layer

- Port & sockets
- UDP
- TCP
  - Error free end-to-end communications
  - Connection oriented
  - Header checksum →covers data and header
  - SN and advertised window in **Bytes**

Transport Layer - TCP continued

- Session setup/teardown
- Estimate RTT → set time out
- Window management for flow control
- Adaptive window for congestion control
  - Action on loss (timeout or duplicate ACKS)
  - Phases
    - Slow start
    - Congestion avoidance
    - Threshold
- RED

MPLS

- Internet mechanism to support VC for aggregate flows
- Language of MPLS
  - Label
  - FEC
  - LDP
  - LSR
  - LSP
- Enables
  - Traffic Engineering
  - QoS for FEC
- GMPLS

At the conclusion of this class the students are expected to:

- Understand the basics of network protocols, including,
  - MAC
  - Data link control,
  - Transport protocols
- Understand the nature of network traffic
- Understand the tradeoffs involved in network design in a variety of environments - LAN and WAN, diverse link rates, and varied error and delay conditions
- Perform simple analytic performance and design trade-off studies
- Be fluent in the language of communication networks, i.e., understand the meaning of networking terms and abbreviations