Part I Syllabus

Lecture	Date	Subject
1	10/08/2016	Introduction
2	10/08/2016	Layered network architecture & Physical resilience
3	17/08/2016	Data link layer – flow control
4	17/08/2016	Data link layer – error control
5	24/08/2016	Data link layer – HDLC
6	24/08/2016	Local area network – introduction
7	31/08/2016	Local area network – MAC
8	31/08/2016	Local area network – Ethernet
9	07/09/2016	Local area network – WLAN
10	07/09/2016	Packet switch network - Introduction
11	14/09/2016	Packet switch network – queue analysis
12	**14/09/2016**	**Review and examples**

CE3002 Computer Networks

Lecture 12
Review and Examples

Contents

- **Part I - Review**
  - Physical layer resilience
  - Data link layer
  - Local area network
  - Packet switched network
  - Queuing theory
- **Part I - Examples**
  - CRACK framework
  - Examples

Part I: Review

Data Link Layer

		Protocol Description	Link Utilization: Percentage of the time during which the link transmits useful information.	Bits for SN	Max Window Size	SN Range	Note
Flow Control	Stop-and-Wait	• Source transmits frame • Destination receives frame and replies with ACK • Source waits for ACK before sending next frame • Destination can stop flow by not sending ACK	$U = \frac{1}{1+2a}$	1	$W = 1$		$a = \frac{T_{prop}}{T_{frame}}$ $T_{prop} = \frac{Distance}{c}$ $T_{frame} = \frac{Length}{Bit\ Rate}$ Note: • convert bytes to bits in calculation • unify all the units in calculation $U = \frac{T_{frame}}{T_{cycle}}$ $U = \frac{r}{R}$ Note: • U is normalized throughput • R is transmission rate • r is throughput
	Sliding Window	• Sender can send up to W frames without receiving ACK • ACK includes number of next frame expected	$U = \begin{cases} 1, & W \geq 1+2a \\ \frac{W}{1+2a}, & W < 1+2a \end{cases}$	k	2^k	$[0, 2^k - 1]$	
ARQ	Stop-and-Wait	• Destination sends an ACK if frame received correctly • Source transmits next frame if ACK is received; otherwise, if no ACK is received within timeout, resource retransmits the frame	$U = \frac{1-P}{1+2a}$	1	1		
	Go-Back-N	• Source transmits frames sequentially based on sliding window • Destination sends ACK normally for error-free frames; otherwise, it sends NAK • Source retransmits that frame with all subsequent frames if NAK is received	$U = \begin{cases} \frac{1-P}{1+2aP}, & W \geq 1+2a \\ \frac{W(1-P)}{(1+2a)(1-P+WP)}, & W < 1+2a \end{cases}$	k	$2^k - 1$	$[0, 2^k - 1]$	
	Selective-Reject	• Receiver informs transmitter of rejected frame n by sending 'SREJ n' • After receiving an erroneous frame, subsequent frames are accepted by receiver and buffered	$U = \begin{cases} 1-P, & W \geq 1+2a \\ \frac{W(1-P)}{(1+2a)}, & W < 1+2a \end{cases}$	k	2^{k-1}	$[0, 2^k - 1]$	

Local Area Network

<table>
<tr><th colspan="2" rowspan="2">MAC Protocols</th><th colspan="3">Transmission Protocol</th><th rowspan="2">Throughput/
Utilization</th><th rowspan="2">Note</th></tr>
<tr><th>Carrier Sensing</th><th>Frame Transmission</th><th>Collision Detection</th></tr>
<tr><td rowspan="2">Aloha</td><td>Slotted</td><td rowspan="2">• None</td><td>• Each transmits in a slot immediately with probability p</td><td rowspan="5">• When a collision is detected, the colliding frames are transmitted up to their last bits.</td><td>$S = Np(1-p)^{(N-1)}$
$= Ge^{-G}$</td><td rowspan="2">Number of Stations: N
Probability of Attempt: p
Attempt Rate: $G = Np$</td></tr>
<tr><td>Pure</td><td>• Each transmits immediately with probability p</td><td>$S = Np(1-p)^{2(N-1)}$
$= Ge^{-2G}$</td></tr>
<tr><td rowspan="3">CSMA</td><td>Non-Persistent</td><td rowspan="3">• Must sense channel before transmission</td><td>• When a busy channel is sensed, a station defers for a random period of time before next sense</td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td>P-Persistent</td><td>• When a busy channel is sensed, a station continues to sense until the channel turns idle. Then, with probability p, it transmits, and with probability $1-p$, it defers to next time slot.</td></tr>
<tr><td>1-Persistent</td><td>• A special case of P-Persistent where $p = 1$</td></tr>
<tr><td colspan="2">CSMA/CD
(Ethernet)</td><td>• Must sense channel before transmission</td><td>• The same as CSMA</td><td>• When a collision is detected, transmissions are aborted to reduce the channel wastage.</td><td>$S = \frac{1}{1 + 6.44a}$
$a = \frac{T_{Prop}}{T_{frame}}$</td><td>Minimum Frame Size
• $T_{frame} \geq 2\tau$
Binary Exponential Backoff
• In i-th retransmission, the slot is chosen from a uniformly distributed random variable R, in the range of $[0, 2^K - 1]$, where $K = \min(i, 10)$.</td></tr>
<tr><td colspan="2">CSMA/CA
(802.11)</td><td>• Must sense channel before transmission</td><td>Sender:
• If sense channel idle for DIFS, then transmit entire frame (no CD).
• If sense channel busy, then start random backoff time. Transmits when timer expires.
• If no ACK, increase random backoff interval
Receiver:
• If frame received OK, return ACK after SIFS</td><td>• No collision detection due to hidden terminal</td><td colspan="2">Multi-Access Reservation
• Use random-access with mini-frame (v unit of time) to reserve the channel
• If reservation successful, transmit u unit of data frame
<table><tr><td></td><td>$\frac{u}{u + v/S_r}$</td><td>$\frac{u}{(u-v) + \frac{v}{S_r}}$</td><td>$\frac{u+v}{u + v/S_r}$</td></tr><tr><td>Total data length</td><td>u</td><td>u</td><td>$u + v$</td></tr><tr><td>Data bit in mini-frame</td><td>No</td><td>Yes</td><td>Yes</td></tr></table></td></tr>
</table>

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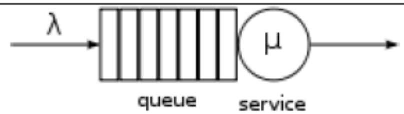
Queuing Theory and MISC

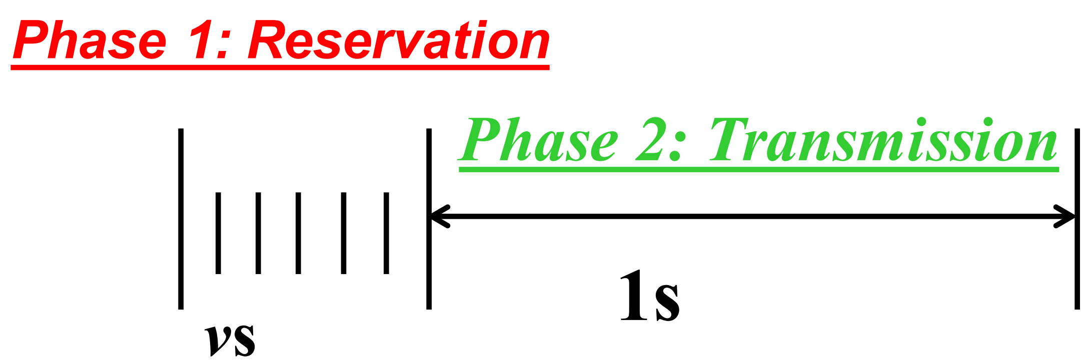
Queue Model	Key Components	Diagram	Input Parameter	Statistics	Note
M/M/1	M/M/1/∞/FCFS		λ : mean packet arrival rate (packet/sec) μ: mean packet service rate (packet/sec) Note: $\lambda < \mu$	Queue Statistics: $\rho = \frac{\lambda}{\mu}$: system utilization $T = \frac{1}{\mu-\lambda}$: average delay $N = \frac{\rho}{1-\rho}$: average queue occupancy $T_q = \frac{\rho}{\mu-\lambda}$: average queuing delay Delay Components for Packet: • Average residual service time: ρ/μ • Average waiting time for early arrival: $(N-\rho)/\mu$ • Average service time: $1/\mu$ • Total delay: $T = \frac{\rho}{\mu} + \frac{N-\rho}{\mu} + \frac{1}{\mu}$	• Splitting Poisson Process: • Merging Poisson Processes • M/M/1 departure process: Poisson process with rate λ • Queue with feedback

Network Design Patterns	HDLC Frame Exchange Sequence	Network Reliability	Packet Transmission Delay in Pipeline
Communication Module • Communication tunnel • Flow control & error control Layering Structure • Four interfaces • NEWS Separation of Mechanism and Policy • Policy: when to do • Mechanism: how to do	High-Level Strategy • One side first • The other next	• Link failure probability: b • Link success probability: $r = 1 - b$ • Links in series $r = \prod_{i=1}^{n} (1 - b_i)$ • Links in parallel $b = \prod_{i=1}^{n} b_i$	Assumptions • N bits, m packets • Header: Lbits/packet • Transmission rate: R bps • # of hops: h End-to-End Delay: no queuing $T = m \times \frac{\frac{N}{m} + L}{R} + (h-1) \times \frac{\frac{N}{m} + L}{R}$

Examples

2011-2012 Semester 1: Question 1

Consider an experimental local area network using a multi-access reservation protocol for data transmission. The protocol consists of two phases. In phase 1, it adopts some MAC protocol for transmission stations to reserve the channel. In phase 2, when one station reserves the channel, it transmits one frame. The length of reservation frame is 5ms, and the length of the data frame is 1s.



2011-2012 Semester 1: Question 1(a)

(a) If the MAC protocol used in phase 1 has a utilization of 0.5, what is the throughput of the multi-access reservation protocol?

Solution:

Step 1: It is a MARP problem

Step 2: the throughput of MARP is $S=1/(1+v/S_r)$

Step 3: $v=5ms$, $S_r=0.5$

Step 4: $S = 1/(1+0.005/0.5)=1/1.01=0.99$

Step 5: $S<=1$

Five-Step Problem-Solving Framework: CRACK

- Step 1: Context
  - What is the context of the problem? List all the given info.
- Step 2: Framework/Strategy
  - What is the framework to tackle it (formula, diagrams, etc)?
- Step 3: Application
  - Apply all the context info into the framework?
- Step 4: Calculation
  - Calculate the results
- Step 5: Check
  - Sanity Check/verification/comment

2011-2012 Semester 1: Question 1(b)

(b) If the slotted Aloha is used in the reservation phase, what is the maximum throughput of the multi-access reservation protocol? Note that the throughput of the slotted Aloha is Ge^(-G), where *G*=*np* is the offer load.

Solution:

Step 1: It is a MARP + Slotted Aloha problem

Step 2: the throughput of MARP is S=1/(1+v/S_r) and S_r=Ge^(-G).

Step 3: To maximize the throughput of Aloha, we have

dS_r/dG=e^(-G)-Ge^(-G)=0

=> G=1 and S_{r, max}=1/e

Step 4: S_{max} = 1/(1+v/S_{r,max})=1/(1+2.71*0.005)=0.9866

Step 5: S<=1

2011-2012 Semester 1: Question 1(c)

(c) Let us assume that a modified CSMA/CD protocol is used in phase 1, which uses the binary exponential backoff scheme to resolve collisions for reservation packets. Moreover, each station is allowed to choose it transmission probability in its retrial. In the case of two stations (A and B) involved in a collision A will retransmit with probability p in slot 0 on window 1 and B will retransmit with probability q in slot 0. What is the probability of a collision occurring in the first retry? How would you choose p and q to minimize the collision probability?

Solution:

Step 1: It is a BEP problem

Step 2: Collision = both stations retransmit in the same slot

Step 3: Pr(Collision) = Pr (A&B in slot 0) + Pr (A&B in slot 1)

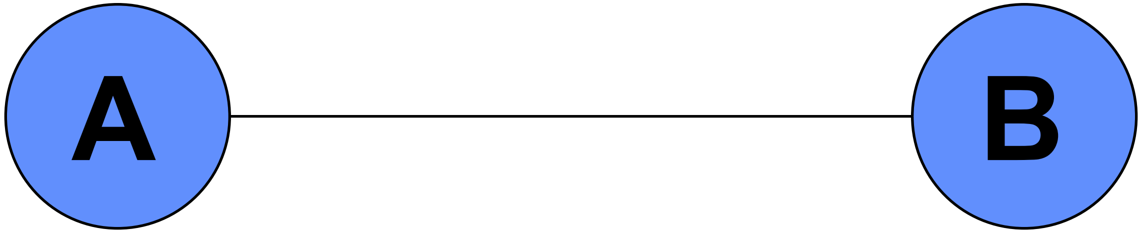
$$= pq + (1-p)(1-q)$$

Step 4: To minimize Pr(Collision), we set p=1, q=0 or p=0, q=1.

Step 5: 0 <=p,q<=1

2011-2012 Semester 1: Question 2

A communication link exists between two nodes A and B. The transmission rate on the link is 2.4 Mbps. The distance between A and B is 50 km and the propagation delay is 2 *μ*s per km. Moreover, there is an admission control module in node A, called traffic shaping, which makes a random decision for each frame admission. The frame length is 300 bytes.



R= 2.b Mbps H=50km

τ=2x50=100μs

L=300 bytes =2400bits

2011-2012 Semester 1: Question 2(a)

(a) We use a sliding window flow control mechanism between A and B. What will be the window size that can maximize the throughput between A and B?

Solution:

Step 1: It is a flow control with sliding window problem

Step 2: the throughput is S= min{1, W/(1+2a)}

Step 3: T_prop = 100μs;

T_{frame}=L/R= 2400bits/2.4Mbps=1000μs

a=T_{prop}/T_{frame}= 100/1000=0.1

Step 4: to maximize the throughput, we have

1<=W/(1+2a) => W >= 1+2a=1.2

=>W_{min} =2.

Step 5: S=1

2011-2012 Semester 1: Question 2(b)

(b) What is the throughput between A and B? Assume the presence of frame transmission errors (the error probability is 10^{-3}) and a stop-and-wait ARQ mechanism between A and B

Solution:

Step 1: It is an error control with stop&wait problem

Step 2: the throughput is $S= (1-P)/(1+2a)$

Step 3: $P=10^{-3}$

$T_{prop} = 100\mu s$;

$T_{frame}=L/R= 2400\text{bits}/2.4\text{Mbps}=1000\mu s$

$a=T_{prop}/T_{frame}= 100/1000=0.1$

Step 4: $S= (1-10^{-3})/(1+2*0.1)=0.999/1.02 = 0.8325$

Step 5: $0<=S<=1$

2011-2012 Semester 1: Question 2(c)

(c) An IP router is connected to the link of Node A. When the external frame arrival rate is 1500 frames per second, will the queue in the router be stable for the cases of Q2(a) and Q2(b)? When the external frame arrival rate is 500 frames per second, what is the average frame delay in the case of Q2(b)? [Note that an M/M/1 queue is used in the router to process frame arrival.]

Solution:

Step 1: It is an M/M/1 problem

Step 2: $\lambda < \mu$; $T=1/(\mu-\lambda)$

Step 3: service rate: μ = 2.4Mbps/2400bits = 1000 frame/sec

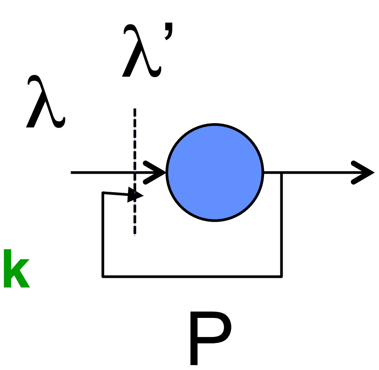
Step 4:

(i) If λ = 1500 frames/sec, queue is not stable

(ii) If λ = 500 frames/sec, $\lambda' = \lambda + \lambda' P \Rightarrow \lambda' = \lambda/(1-P)$

$T=1/(\mu-\lambda')=1/(1000-500/0.999) = 2.002\text{ms}$

Step 5: ARQ can be modeled as a queue with feedback




GOOD LUCK
IN YOUR EXAMS
knock 'em out with your GENIUS!