Advanced Network Technologies

Introduction

Dr. Wei Bao | Lecturer
School of Computer Science

THE UNIVERSITY OF SYDNEY

- Title: Advanced Network Technologies
- UOS code: COMP5416
- Credit point: 6
  - Wednesday 18:00-20:00, weeks 1-13
  - Online
- Lab/Tutorial:
  - Wednesday 20:00-21:00, weeks 1-13, today
  - Thursday 17:00-18:00, weeks 1-13
  - Sydney time by default
  - Note your time zone, especially ADST/AEST change in October.
  - Online

People

- Wei Bao, *Coordinator and Lecturer*
  - Weeks 1-13
  - Office: J12-4W-425
  - Phone: (02) 8627 4365
  - wei.bao@sydney.edu
  - https://www.sydney.edu.au/engineering/our-people/academic-staff/wei-bao.html
  - Office hour: By appointment, through Zoom
  - Clearly note COMP5416 in the email title when you contact me
- Background
  - Research: Networking, Mobile Computing, Internet of Things, Distributed Systems.
  - Research Group: Centre for Distributed and High Performance Computing (http://sydney.edu.au/distributed_computing/)
  - University of Toronto

People

- Zhengjie Yang, *Tutor*
  - Weeks 1-13
  - Office: J12-West Wing
  - zhengjie.yang@sydney.edu.au
  - Office hour: by appoi
- Background
  - Research: Networking, mobile computing, chine learning.
  - 4-year experience in tutoring this UoS
- Da Xie, *Tutor*
  - Weeks 1-13
  - Office: J12-West Wing
  - dxie4155@uni.sydney.edu.au
  - Office hour: by appointment, through Zoom

Emergency procedures (on campus)

- In the unlikely event of an emergency we may need to evacuate the building.
- If we need to evacuate, we will ask you to take your belongings and follow the green exit signs.
- We will move a building and maintain physi ting until the emergency is over.
- In some circumstances, we m ed to remain inside the building for our own safety. We call this a lockdown or shelter-in-place.
- Further information is available at **www.sydney.edu.au/emergency**

Keeping our community safe

We can all help reduce the spread of COVID-19 through following good hygiene practices:

- **Wash hands regularly**, for at least 20 seconds with soap and water, or use an alcohol-based hand rub.
- **Cover your** **g and sneezing** with a tissue or
- Maintain a **distance of at l** between yourself and others, where po
- **Avoid large gatherings**, where possible.
- **Avoid close contact** with anyone **with cold or flu symptoms**, e.g. fever, cough, runny nose or shortness of breath.

Keeping our community safe

- All students and staff who have cold or flu symptoms should **isolate** themselves from others.
- If you are unwell with cold or flu symptoms **please excuse yourself from this class** and we will support you to tely.
- Make sure you **special consideration** in the unit o

Keeping our community safe

- The University is following advice from the government and related public health authorities.
- For the latest information, see the advice on the University website.
- In some classe lving use of shared equipm onal advice from your coordinators.
- Please take care of each oth selves and if you need support reach out to your unit coordinator or the health and wellbeing area of the Current Students website.

Tips for students joining online

- Remember that you are still in a space with other students.
- Mute your microphone when not speaking.
- Use earphones or headphones - the mic is better and you'll disturb ot
- If you have a w on so we can see you!
- If you are speaking to the cam eye contact with the camera (and therefore your classmates and teacher).
- Try not to talk over someone else.
- Use the chat function to send messages to the teacher or classmates during class.

Tips for students learning online

- For tips and guides on learning online and the tools you will use, refer to Learning while off campus resources in Canvas.

Resources

Canvas: https://canvas.sydney.edu.au/

- Login using Unikey and password
- Link to Units website: https://sydney.edu.au/units/
  - Official schedule, list of learning outcomes, etc
- Copies of slides
- Lab instructions
- Assignment instructio
- Lecture videos
  - We intend to record the lectures, but y is not reliable
- *Submit official assignment work here*;
- see your grades; etc

Textbook and material

Computer Networking: A TopDown Approach 6th or 7th edition, Jim Kurose and Keith Ross,

Expectations

- Students attend scheduled classes, and devote an *extra* 6-9 hrs per week
  - doing assessments
  - preparing and reviewing for classes
  - revising and integrating the ideas
  - practice and self-asse
- Students are responsible l
  - Participate in classes, constructively
    - Respect for one another (criticize ideas
    - Humility: none of us knows it all; each of us knows valuable things
  - Check canvas site at least once a week!
  - Notify academics whenever there are difficulties

Evaluation

- W6: Assignment 1, 20%

  Covers W1—W6

- W12: Assignment 2, 20%

  Covers W6—W12

- Exam period: Final ex

  Covers everything

- School of CS policy: you must get at least 40% of the marks available on the exam, in order to pass the unit. (40% barrier on exam, less than 40% in the exam is automatically a FAIL.)

Special Consideration (University policy)

- If your performance on assessments is affected by illness or misadventure
- Follow proper bureaucratic procedures
  - Have professional practitioner sign special USyd form
  - Submit application , upload scans
  - Note you have onl ying
  - http://sydney.edu.au/current_students deration/
- Also, notify coordinator by email *as soon as anything begins to go wrong*
- There is a similar process if you need special arrangements eg for religious observance, military service, representative sports

Late assessments

- Suppose you hand in work after the deadline:
- Penalty of 5% per day late, e.g.:
  - A good assignment that would normally get 8/10 and is 2 days late loses 10% of the full 10 marks
  - An average assign /10 and is 5 days late loses 25% of the full 10 marks, i.e. new mar
  - Assignments more than 10 days late g
- Warning: submission sites get very slow near deadlines.
- You can resubmit if there is time before the deadline. Only the latest version will be marked.

Academic Integrity (University policy)

- "The University of Sydney is unequivocally opposed to, and intolerant of, plagiarism and academic dishonesty.
  - Academic dishonesty means seeking to obtain or obtaining academic advantage for oneself or for others (including in the assessment or publication of work) by dishon
  - Plagiarism means rk as one's own work by presenting, copying or reproducing it iate acknowledgement of the source." [from site below]
- http://sydney.edu.au/elearning/student/EI/index.shtml
- Submitted work is compared against other work (from students, the internet etc)
  - Turnitin
- Penalties for academic dishonesty or plagiarism can be severe
- Complete self-education AHEM1001

DISABILITY SERVICES

Do you have a disability?

You may not think of yourself as having a 'disability' but the definition under the **Disability Discrimination Act** is broad and includes temporary or chronic medical conditions, physical or sensory disabilities, psychological conditions and learning disabilities.

The types of disabilities we s

anxiety, arthritis, asthma, asperger's disorder, ADHD, bipolar dis , cancer, cerebral palsy, chronic fatigue syndrome, crohn's disease, cystic fibrosis, depression, dia psy, hearing impairment, learning disability, mobility impairment, multiple sclerosis, post traumatic , vision impairment, and much more.

Students needing assistance must register with Disability Services –

it is advisable to do this as early as possible.

http://sydney.edu.au/study/academic-support/disability-support.html

Other support

Learning support

http://sydney.edu.au/study/academic-support/learning-support.html

International students

http://sydney.edu.au/stu ernational-students.html

Aboriginal and Torres Strait I

http://sydney.edu.au/study/academic-support/a rres-strait-islander-support.html

Student organization (can represent you in academic appeals etc)

http://srcusyd.net.au/ or http://www.supra.net.au/

Please make contact, and get help

You are not required to tell anyone else about this

If you are willing to inform the unit coordinator, they may be able to work with other support to reduce the impact on this unit

eg provide advice on which tasks are most significant

Advice

Metacognition

- Pay attention to the learning outcomes
- Self-check that you are achieving each one
- Think how each assess

Time management

- Watch the due dates
- Start work early, submit early

Networking and community-formation

- Make friends and discuss ideas with them
- Know your tutor, lecturer, coordinator
- Keep them informed, especially if you fall behind
  - Don’t wait to get help

Enjoy the learning!

Syllabus

1. Introduction, Network overview
2. Network performance, Application layer 1
3. Application 2
4. Transport 1
5. Transport 2
6. Network science: queues
7. Multimedia network 1
8. Multimedia network 2
9. Wireless and Mobile 1
10. Wireless and Mobile 2
11. Advance Network Protocols
12. Network science: Network optimization*
13. Recent advances in Network*, Review

1. Basic network performance analysis
2. Wireshark, HTTP packet sniffing
3. Python socket programming
4. Math foundations for network analysis
   layer and TCP
   nd queue simulator
   a network
   otocol
   nd Queues
10. Network programming
11. Wireless and noise
12. Internet of Things Experiment
13. T: Review and Q&A

Goals

Facts/Knowledge

› How is information transported?

› How to make communications efficient?

› Why does it work in this way? (Differentiate this unit from basic-level units.)

Theory

› Tutorials: Use math to solve pr

› Why is math important?

Practice

› Labs: will require programming

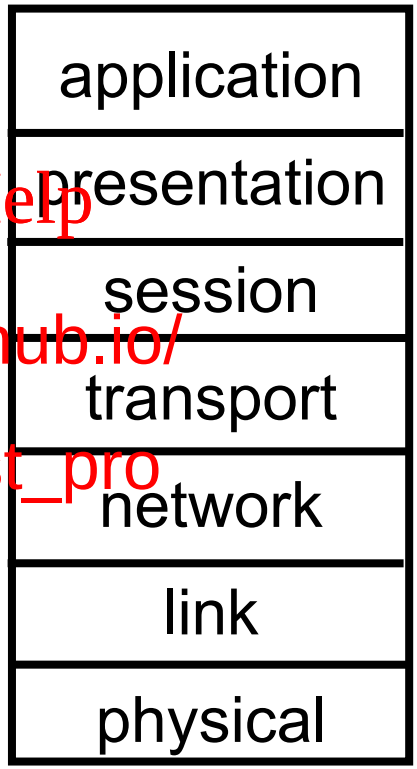
› All programming will be done in Python (version 3.X)

You should be fine if you know Java/C

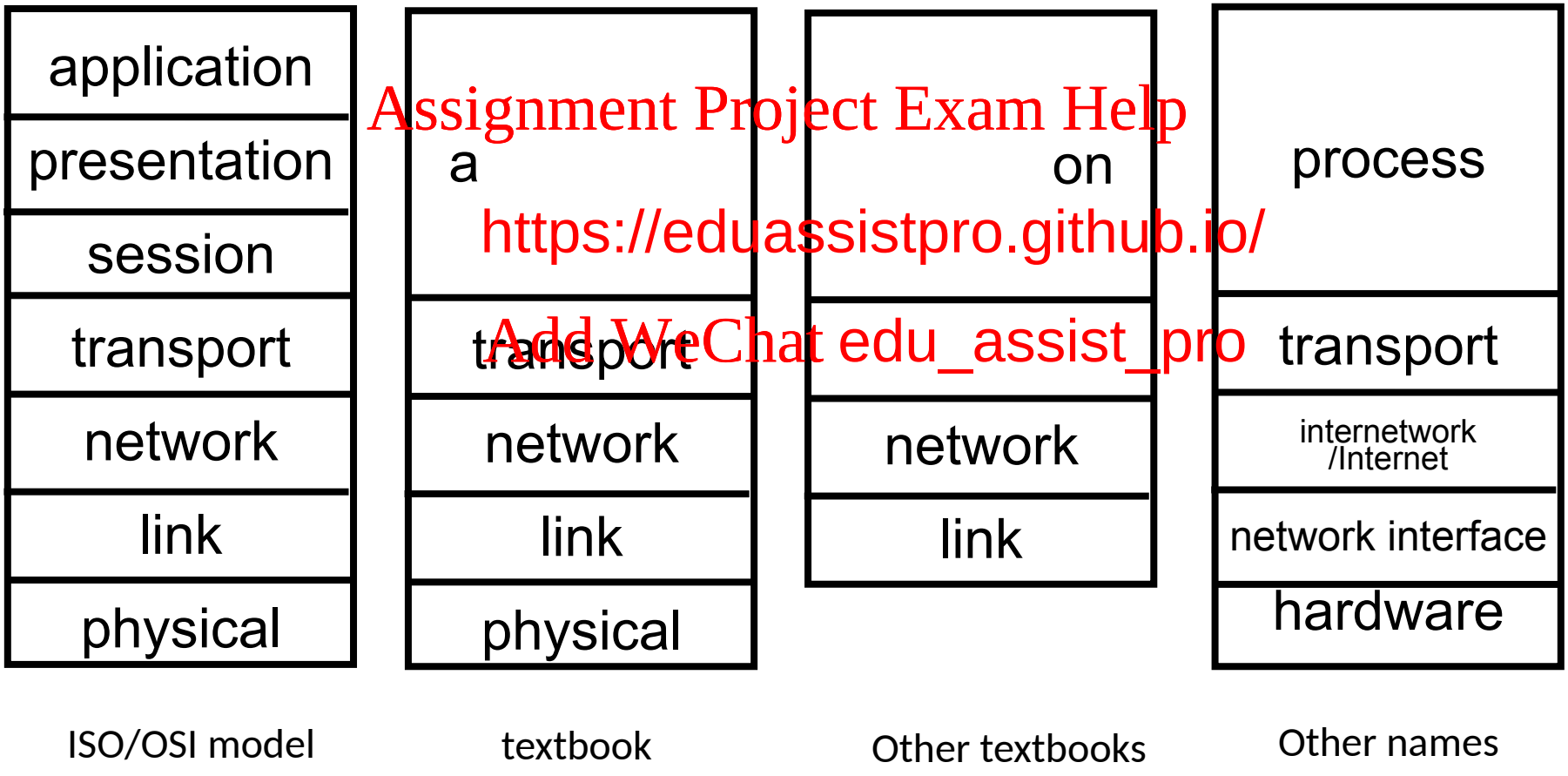
› Wireshark experiment

ISO/OSI model

- *ISO: International Organization for Standardization*
- *OSI: Open Systems Interconnection*



Network Layers



Network Layers

How to provide network applications satisfies users?	Application
How to provide end-to-end running at different de	Transport
How to send message to non-adjacent nodes?	Network
How to organize data transfer among adjacent network nodes?	Link
How to transfer bits from one device to another?	Physical

Physical Layer

Role: Transmitting raw bits over a physical link connecting network nodes.

http://www.eetimes.com/document.asp?doc_id=1276305

Role: data transfer between neighboring network elements.

Bit error detection:

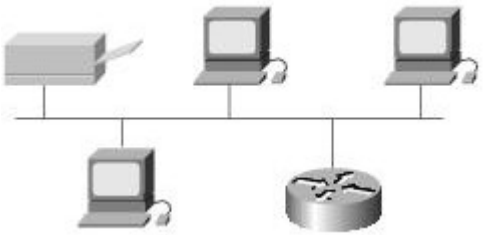
Sender 010101, receiver 010100

Medium access control:

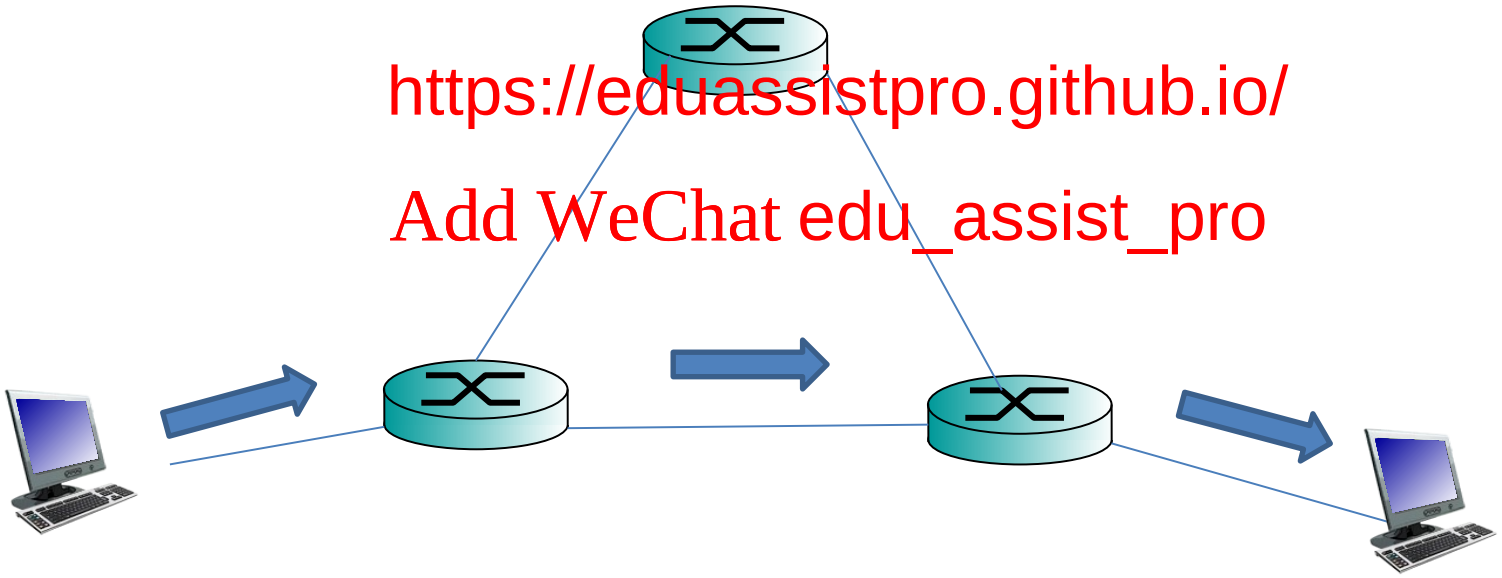
Tw

Link-layer addressing:

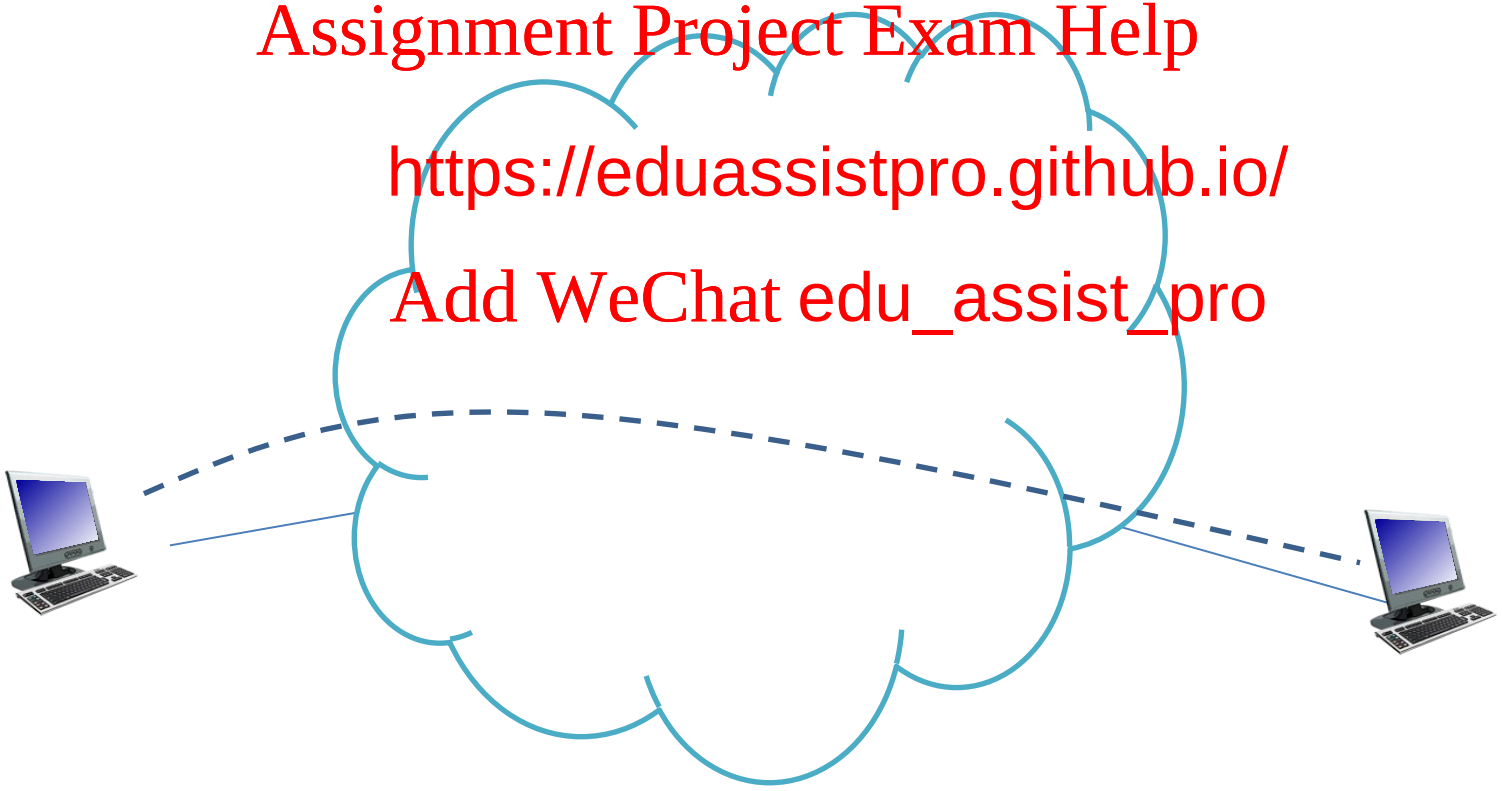
This information is for yo



Role: routing and forwarding packets from (every) source to (every) destination

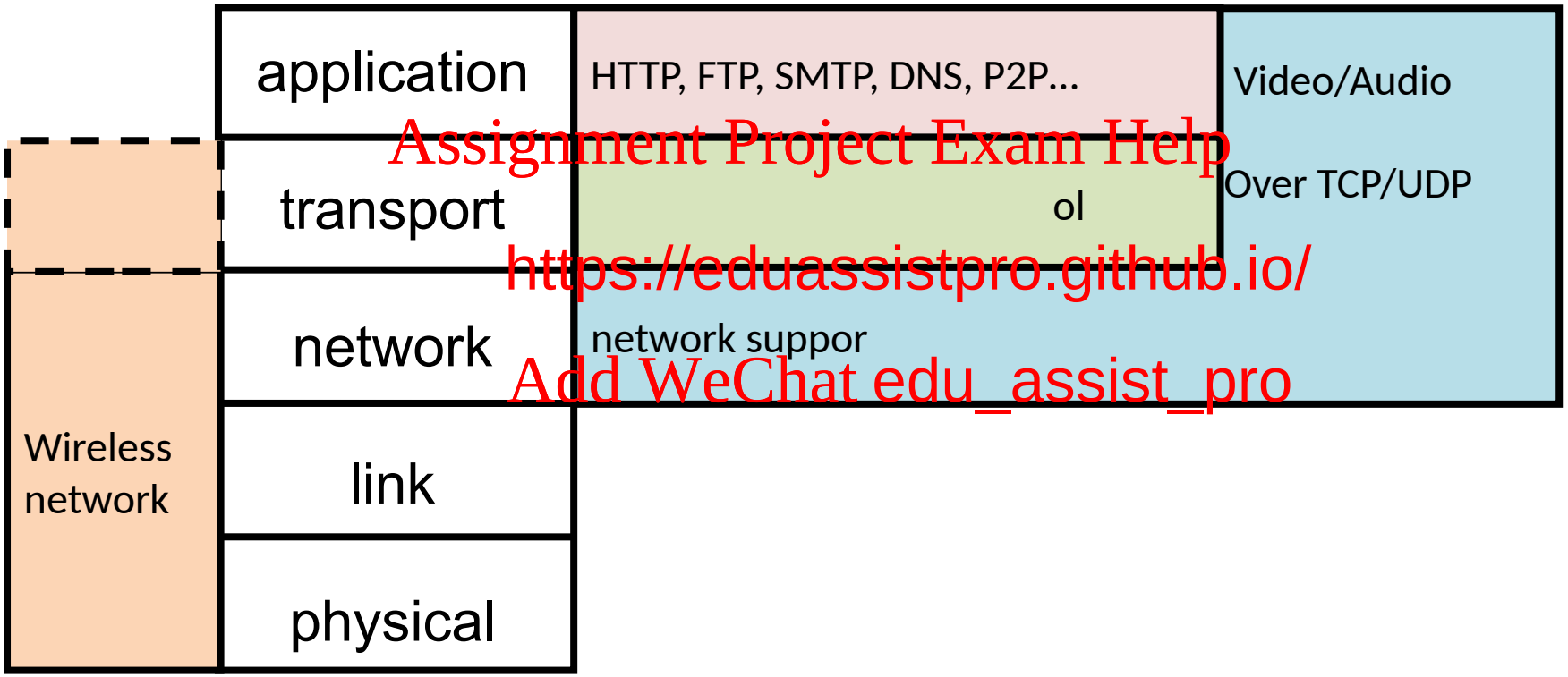


Role: manage program-program (process-process) data transfer

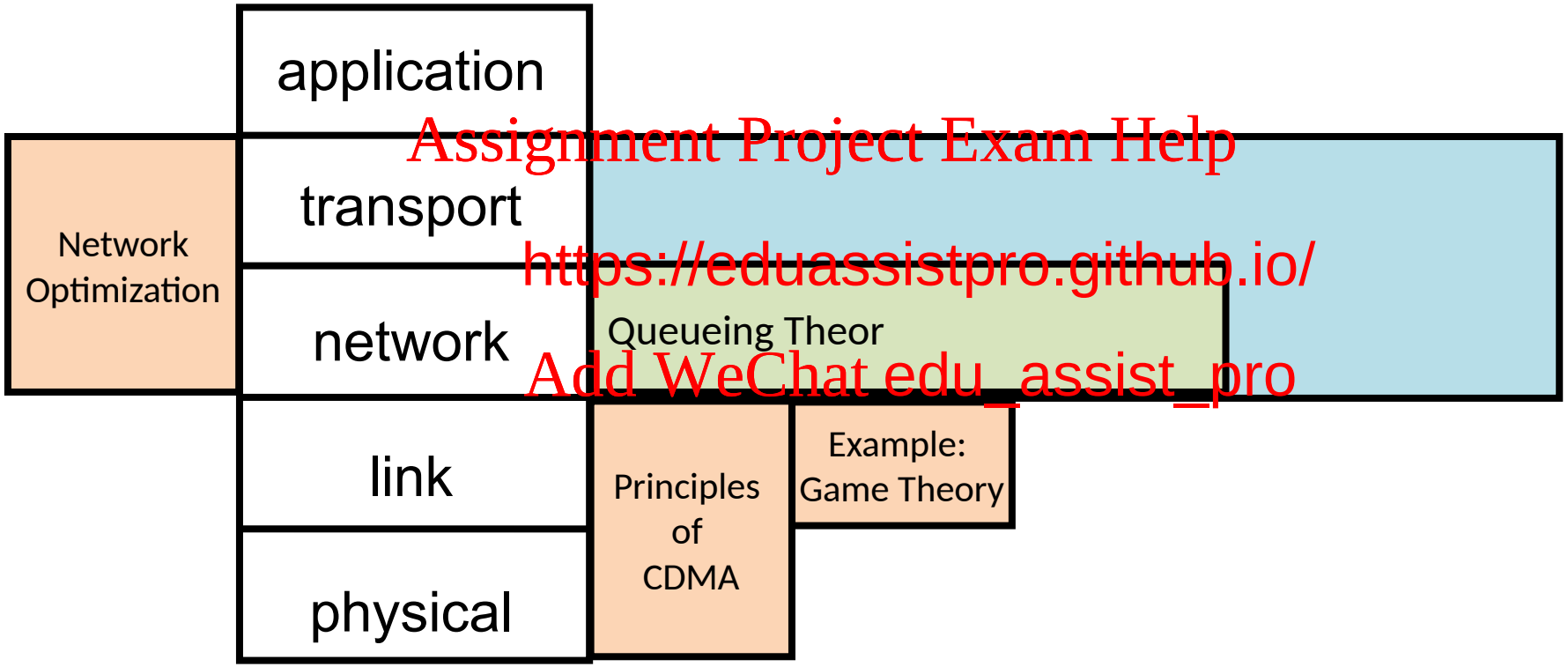


Role: support network applications

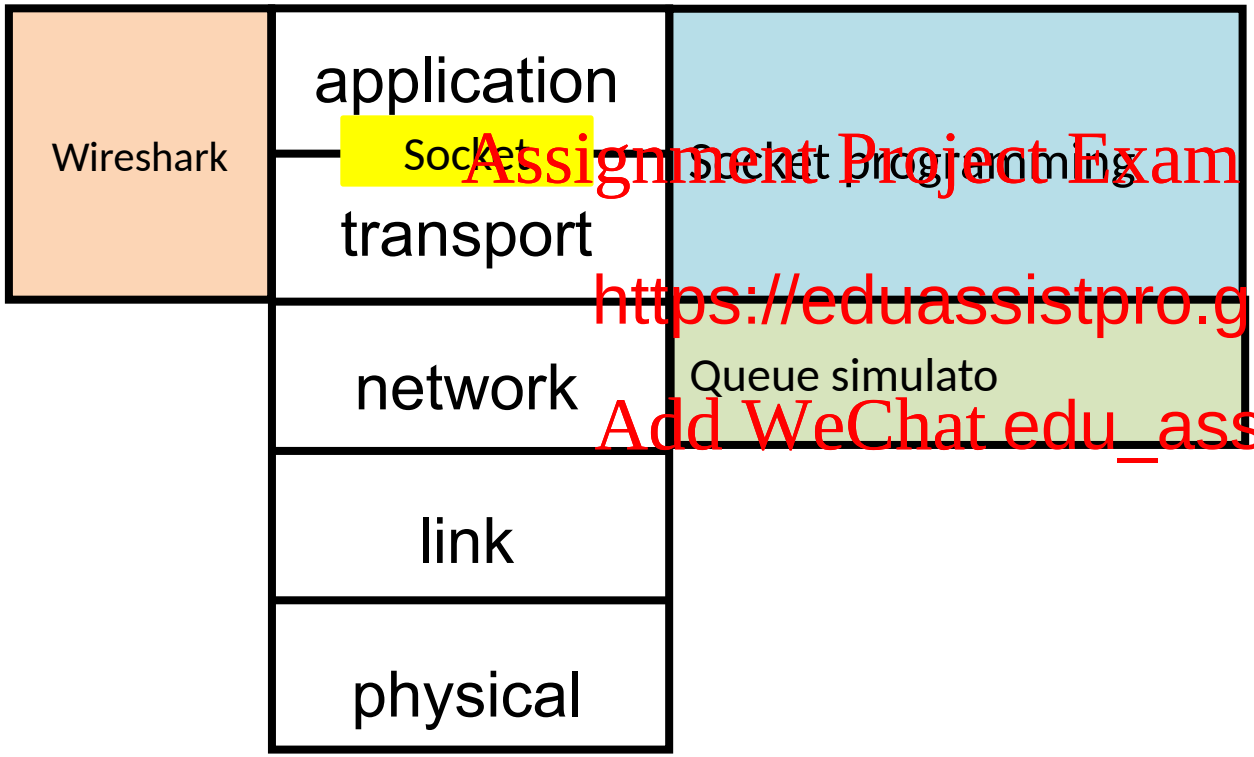
Preview: Practice



Preview: Theory



Preview: Programming/Experiment

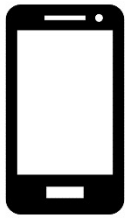


Network analysis example

Two users competing for one channel

User 1

User 2

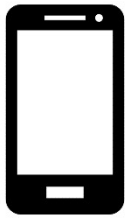


Two users competing for one channel

A collision happens! No one is successful!

User 1

User 2



Two users competing for one channel

Situations	User 1's benefit	User 2's benefit
1 off, 2 off	0	0
1 on, 2		
1 off, 2		
1 on, 2 on	-5	

Two users competing for one channel

Situations	User 1's benefit	User 2's benefit
1 off, 2 off	0	0
1 on, 2		
1 off, 2		
1 on, 2 on	-5	

In cellular network, for example, we can schedule 1 and 2 in a fair way.

In many other situations? Selfish users.

Two users competing for one channel

Situations	User 1's benefit	User 2's benefit
1 off, 2 off	0	0
1 on, 2		
1 off, 2		
1 on, 2 on	-5	

Solution: Game Theory!

Mathematical models of conflict and cooperation between intelligent rational decision-makers!

Useful to solve ma

Also useful to analyse computer n

the Internet!

Prisoner's dilemma

Two members of a criminal gang are arrested

Each prisone

communica

Each prisoner can:

1 confess

2 keep silent

Prisoner's dilemma

Result

Both confes prison

Both keep silent: both ser n prison

A confesses, B keeps silent (vice versa):

A is set free

B serves 10 years in prison

Prisoner's dilemma

A's decision / (A, B) utility / B's decision	Confess	Keep silent
Confess		-10,0)
Keep silent	(0,-10)	(-1,-1)

Nash Equilibrium

A's decision / (A, B) utility / B's decision	Confess	Keep silent
Confess		-10,0)
Keep silent	(0,-10)	(-1,-1)

The tuple satisfies: no player has anything to gain by changing only his own strategy

Nash Equilibrium

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Nash Equilibrium

A's decision / (A, B) utility / B's decision	Confess	Keep silent
Confess		-10,0)
Keep silent	(0,-10)	(-1,-1)

B changes his/decision, Yes

The tuple satisfies: no player has anything to gain by changing only his own strategy

Nash Equilibrium

A's decision / (A, B) utility / B's decision	Confess	Keep silent
Confess		-10,0)
Keep silent	(0,-10)	(-1,-1)

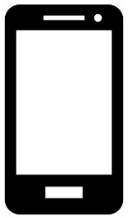
Not a Nash Equilibrium !

The tuple satisfies: no player has anything to gain by changing only his own strategy

Back to our problem

User 1

User 2



Back to our problem

1's decision / (1, 2) utility / 2's decision	Transmit	Keep silent
Transmit		0,10)
Keep silent	(10,0)	(0,0)

Nash Equilibrium?

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Back to our problem

1's decision / (1, 2) utility / 2's decision	Transmit	Keep silent
Transmit		0,10)
Keep silent	(10,0)	(0,0)

Two Nash Equilibria

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Back to our problem

1's decision / (1, 2) utility / 2's decision	Transmit	Keep silent
Transmit		0,10)
Keep silent	(10,0)	(0,0)

Two Nash Equilibria

Pure and mix strategy

This is still not ideal.

Solution: mixed strategy.

Each player c istic decision!

User 1: trans ty p1

keep silent with lity (1-p1)

User 2: transmit with probability p2

keep silent with probability (1-p2)

Back to our problem

1's decision / (1, 2) utility / 2's decision	Transmit	Keep silent
Transmit	p1*p2	0,10) p1)*p2
Keep silent	(10,0) p1*(1-p2)	(0,0) (1-p1)*(1-p2)

-5*p1*p2+10*p1*(1-p2)+0*(1-p1)*p2+0*(1-p1)*(1-p2)
= -5*p1*p2+10*p1*(1-p2)

So what?

Let's try p2=2/3

User 1's average utility

-5*p1*p2+10*

=-5*p1*2/3+10

=0

No matter how to change p1, user 1's utility is 0

Similarly

If p1=2/3

No matter how to change p2, user 1's utility is 0

So what?

p1=p2=2/3 is a Nash Equilibrium

Why?

User 1's avera

If p2=2/3

No matter how to change 's utility is 0

If p1=2/3

No matter how to change p2, user 1's utility is 0

What happens if users are cooperative?

If the users are not selfish,

p1=p2=1/3 is on

User 1's average utility i

User 2's average utility is 5/3

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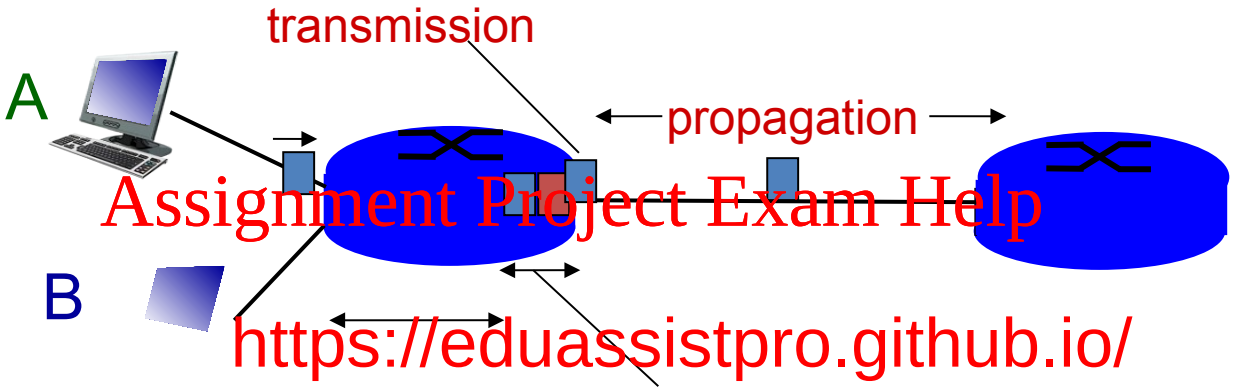
Network performance in summery

Situations	Solution	Utility
Selfish users	p1=2/3, p2=2/3	(0,0)
Cooperative users		,5/3)

Delay

Four sources of packet delay



$d_{nodal} = d_{proc} + d_{queue} + d_{trans} +$

d_{proc}: nodal processing

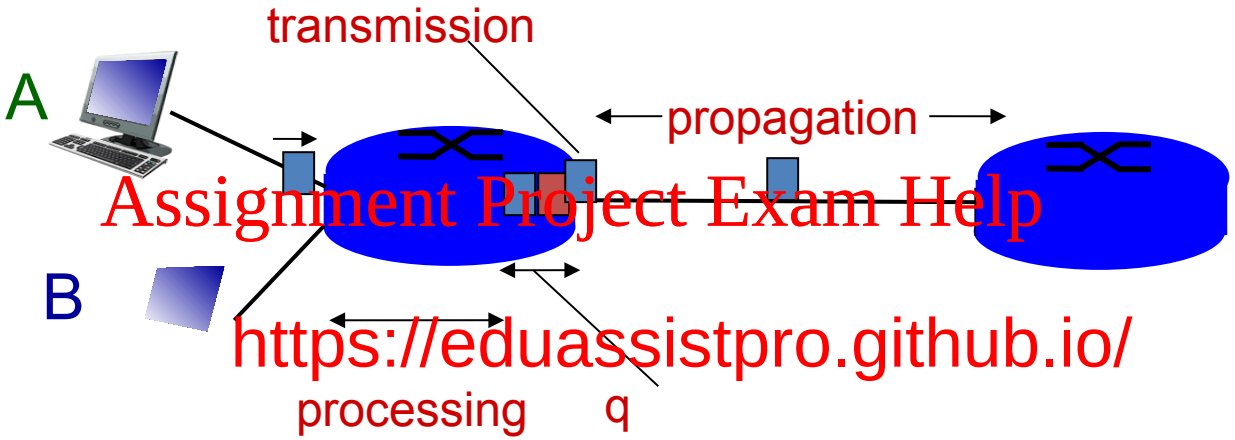
- check bit errors
- determine output link
- typically < msec

d_{queue}: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router

Delay

Four sources of packet delay



$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$

d_{trans}: transmission delay:

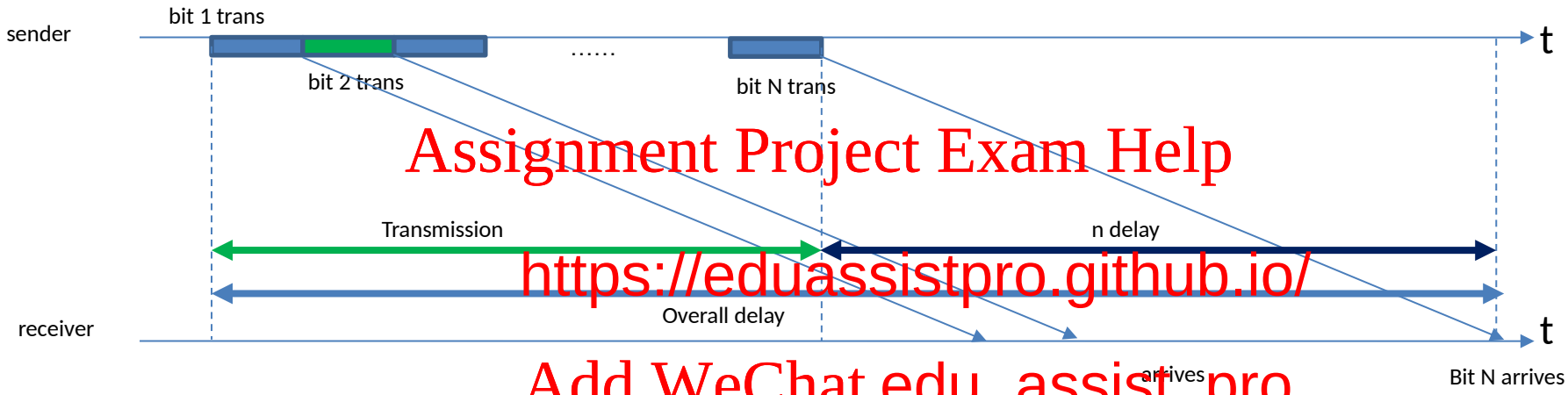
- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{prop}: propagation delay:

- d: length of physical link
- s: propagation speed in medium (~2×10^8 m/sec)
- $d_{prop} = d/s$

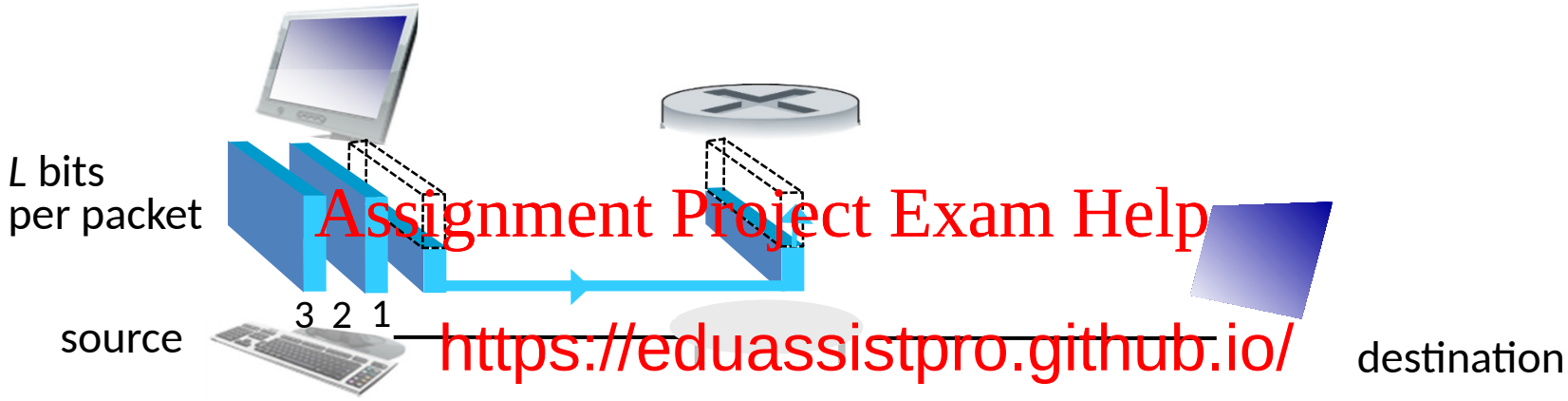
d_{trans} and d_{prop} *very* different

Transmission Delay and Propagation Delay



Store and Forward

Store-and-forward



- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- *end-end delay:* 2 *L*/*R* (assuming zero propagation delay)

rical example:

- *L* = 7.5 Mbits
- *R* = 1.5 Mbps
- delay = 5 sec

Queueing delay

- *R*: link bandwidth (bps)
- *L*: packet length (bits)
- a: average packet

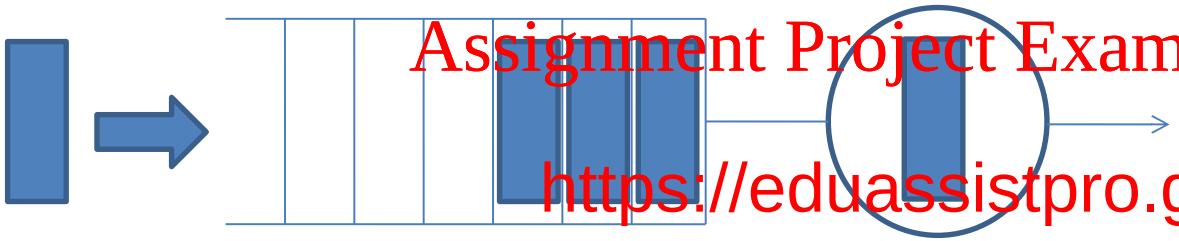
ity = La/R

- *La/R* ~ 0: avg. queueing delay small
- *La/R* <~ 1: avg. queueing delay large
- *La/R* > 1: more "work" arriving than can be serviced, average delay infinite!

La/R ~ 0

La/R <~ 1

A Brief Discussion on Queueing Theory



Queue

Properties of a Queue

- *Job arrival*
- *Job service time*
- *Number of servers*
- *Queue size*
- *Service disciplines*

Properties of a Queue

- *Job arrival*
  - Poisson process
  - Number of arrivals
  - Distribution of N(t

  - Mean: $E(N(t)) = \lambda t$
  - Arrival rate λ

Properties of a Queue

- *Job service time*

  - *Exponential distri*
  - PDF: probability
  - CDF: Cumulative distribution f $1 - e^{-\mu x}$
  - Mean: $1/\mu$
  - Can serve μ jobs per unit time.
  - Service rate: μ

Properties of a Queue

- *Number of servers*
  - *1*
- *Queue size*
  - *Infinity*
- *Service disciplines*
  - *First in first served*

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Properties of a Queue

- *Conclusions*
- *Mean waiting time*
- *1/(μ- λ)*
- *Derivation will be shown later.*