

# Advanced Network Technologies

Introduction

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Dr. Wei Bao | Lecturer  
School of Computer Science



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SYDNEY

- › Title: Advanced Network Technologies
- › UOS code: COMP5416
- › Credit point: 6

## Assignment Project Exam Help

- Wednesday 18:00-20:00, weeks 1-12

- Online

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- › Lab/Tutorial:

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- Wednesday 20:00-21:00, weeks 1-12, today
  - Thursday 17:00-18:00, weeks 1-12
  - Sydney time by default
  - Note your time zone, especially ADST/AEST change in October.
  - Online
-

› Wei Bao, *Coordinator and Lecturer*

- Weeks 1-12
- Office: J12-4W-425

- Phone: (02) 8627 4865

- [wei.bao@sydney.edu.au](mailto:wei.bao@sydney.edu.au)

- <https://www.sydney.edu.au/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/](http://sydney.edu.au/distributed_computing/))
- University of Toronto



› Zhengjie Yang, *Tutor*

- Weeks 1-12
- Office: J12-West Wing
- [zhengjie.yang@sydney.edu.au](mailto:zhengjie.yang@sydney.edu.au)
- Office hour: by appoint

› Background

- Research: Networking, mobile computing, machine learning.
- 3-year experience in tutoring this UoS

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# 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 physical distance of 1.5 metres between buildings and maintain physical distancing until the emergency is over.
- In some circumstances, we might remain inside the building for our own safety. We will conduct a lockdown or shelter-in-place.
- Further information is available at [www.sydney.edu.au/emergency](https://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
  - **Cover your mouth** <https://eduassistpro.github.io/> with a tissue or a flexed elbow
  - Maintain a **distance of at least 1** [Add WeChat edu\\_assist\\_pro](#) n-yourself and others, where possible.
  - **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 continue the work remotel
- Make sure you r **cial consideration** in the unit outline.

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# 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](#). **Assignment Project Exam Help**
  - In some classes, use of shared equipment, please <https://eduassistpro.github.io/> e from your coordinators. **Add WeChat edu\_assist\_pro**
  - Please take care of each other 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 others less.
- If you have a webcam, turn it on so we can see you!
- If you are speaking, use the chat function to contact with the teacher.
- Try not to talk over someone else.
- Use the chat function to send messages to the teacher or classmates during class.

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# 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.

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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 **Assignment Project Exam Help**

Lab instructions

Assignment instructio

Lecture videos

<https://eduassistpro.github.io/>

We intend to record the lectures, but y is not reliable

*Submit official assignment work here;* **Add WeChat edu\_assist\_pro**

see your grades; etc

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

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Some of the information on the slides of this course is taken from the companion material of this textbook that is subject to copyright 1996-2012, J.F Kurose and K.W. Ross, All Rights Reserved.

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- 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-as
- Students are responsible
  - Participate in classes, constructively
    - Respect for one another (criticize id
    - 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

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- › W6: Assignment 1, 20%

Covers W1—W5

- › W12: Assignment 2, 20%

Covers W6—W11

- › Exam period: Final ex

Covers everything

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- › 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 UoSy form
  - Submit application, upload scans
  - Note you have only <https://eduassistpro.github.io/> ying
  - [http://sydney.edu.au/current\\_students/special\\_consideration/](http://sydney.edu.au/current_students/special_consideration/)
- 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

- Suppose you hand in work after the deadline:
- Penalty of 5% per day late, e.g.:
  - A good assignment that would normally get 9/10 and is 2 days late loses 10% of the full 10 marks
  - An average assignment that would normally get 7/10 and is 5 days late loses 25% of the full 10 marks, i.e. new mark is 5.25
  - Assignments more than 10 days late are marked 0
- 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.

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# 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 dishonesty
  - Plagiarism means presenting, copying or reproducing it as one's own work by the source.” [from site below]iate acknowledgement of
- <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

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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 see <https://eduassistpro.github.io/>

anxiety, arthritis, asthma, asperger's disorder, ADHD, bipolar disorder, cancer, cerebral palsy, chronic fatigue syndrome, crohn's disease, cystic fibrosis, depression, epilepsy, hearing impairment, learning disability, mobility impairment, multiple sclerosis, post traumatic stress disorder, 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>

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## Learning support

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

International students **Assignment Project Exam Help**

<http://sydney.edu.au/study/academic-support/international-students.html>

Aboriginal and Torres Strait **https://eduassistpro.github.io/**

<http://sydney.edu.au/study/academic-support/aboriginal-and-torres-strait-islander-support.html>

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Student organization (can represent you in academic matters)

<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

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## 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!

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<https://www.sydney.edu.au/units/COMP5416>

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- |   |   |
|---|---|
| 1. Introduction, Network overview           | 1.T: Basic network performance analysis |
| 2. Network performance, Application layer 1 | 2.L: Wireshark, HTTP packet sniffing    |
| 3. Application 2                            | 3.L: Python socket programming          |
| 4. Transport 1                              | 4.T: Math for network analysis          |
| 5. Transport 2                              | ort layer and TCP                       |
| 6. Network science: queue                   | rk and queue simulator                  |
| 7. Multimedia network 1                     | edia network                            |
| 8. Multimedia network 2                     | protocol                                |
| 9. Wireless and Mobile 1                    | g and Queues                            |
| 10. Wireless and Mobile 2                   | 10.L: Network programming               |
| 11. Network science: Network optimization*  | 11.T: Wireless and noise                |
| 12. Recent advances in Network*, Review     | 12.T: Review and Q&A                    |

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## 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

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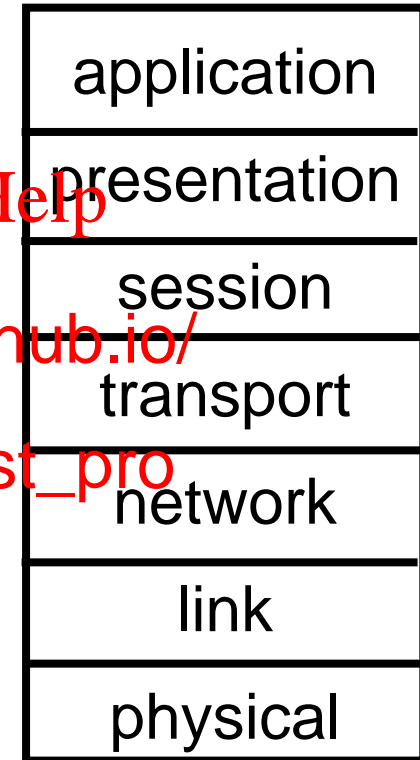


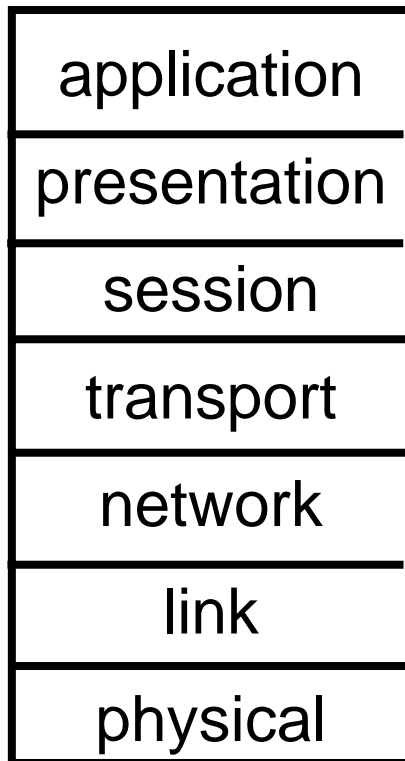
- › *ISO: International Organization for Standardization*
- › *OSI: Open Systems Interconnection*

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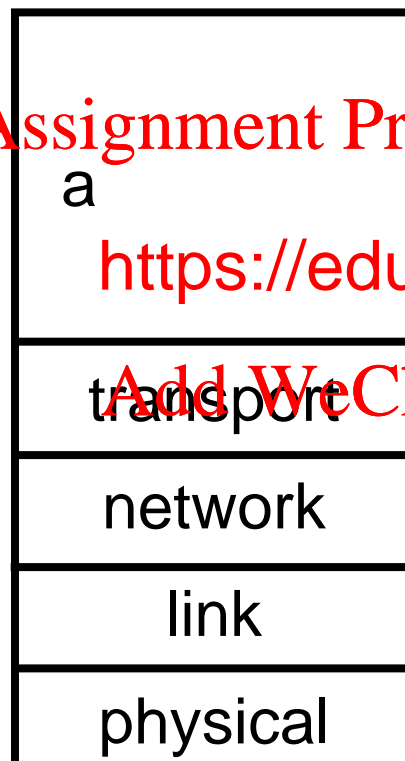
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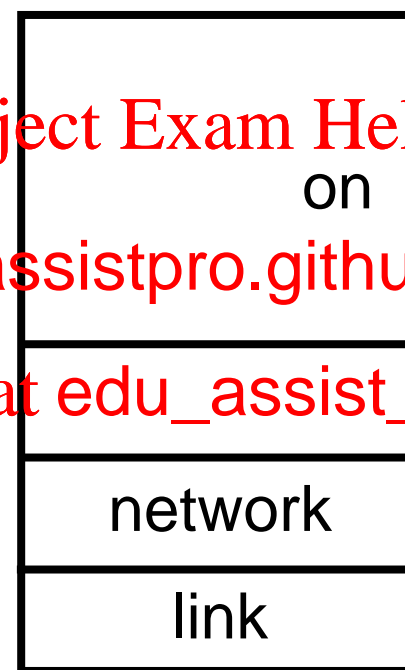




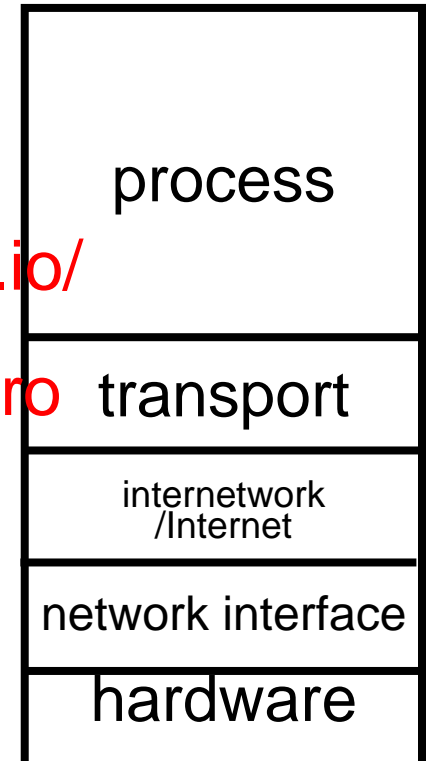
ISO/OSI model



textbook



Other textbooks



Other names

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How to provide network applications satisfies users?

How to provide end-to-end  
running at different de

How to send message to non-adjacent nodes?

How to organize data transfer among  
adjacent network nodes?

How to transfer bits from one device to another?

Application

Transport

Network

Link

Physical

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

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[http://www.eetimes.com/document.asp?doc\\_id=1276305](http://www.eetimes.com/document.asp?doc_id=1276305)

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Role: data transfer between neighboring network elements.

Bit error detection:

Sender 010101, receiver 010100

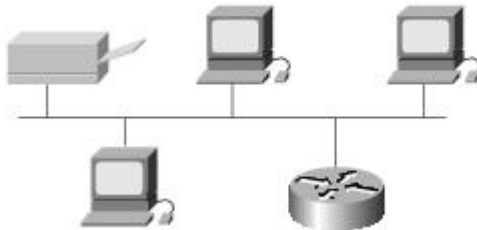
Medium access control:

Tw

Link-layer addressing:

This information is for yo

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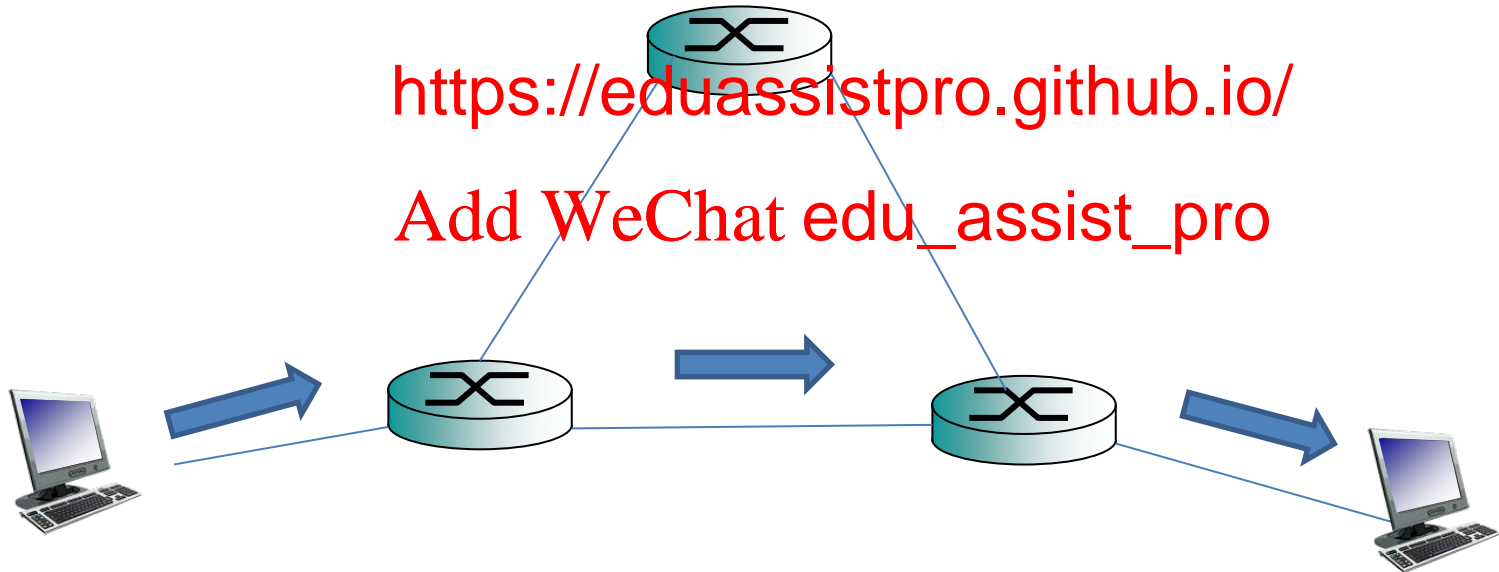


Role: routing and forwarding packets from (every) source to (every) destination

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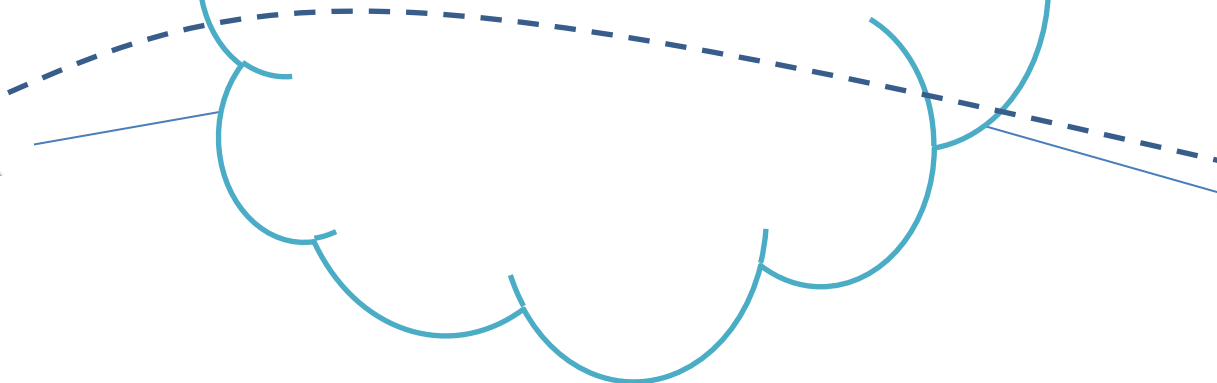


Role: manage program-program (process-process) data transfer

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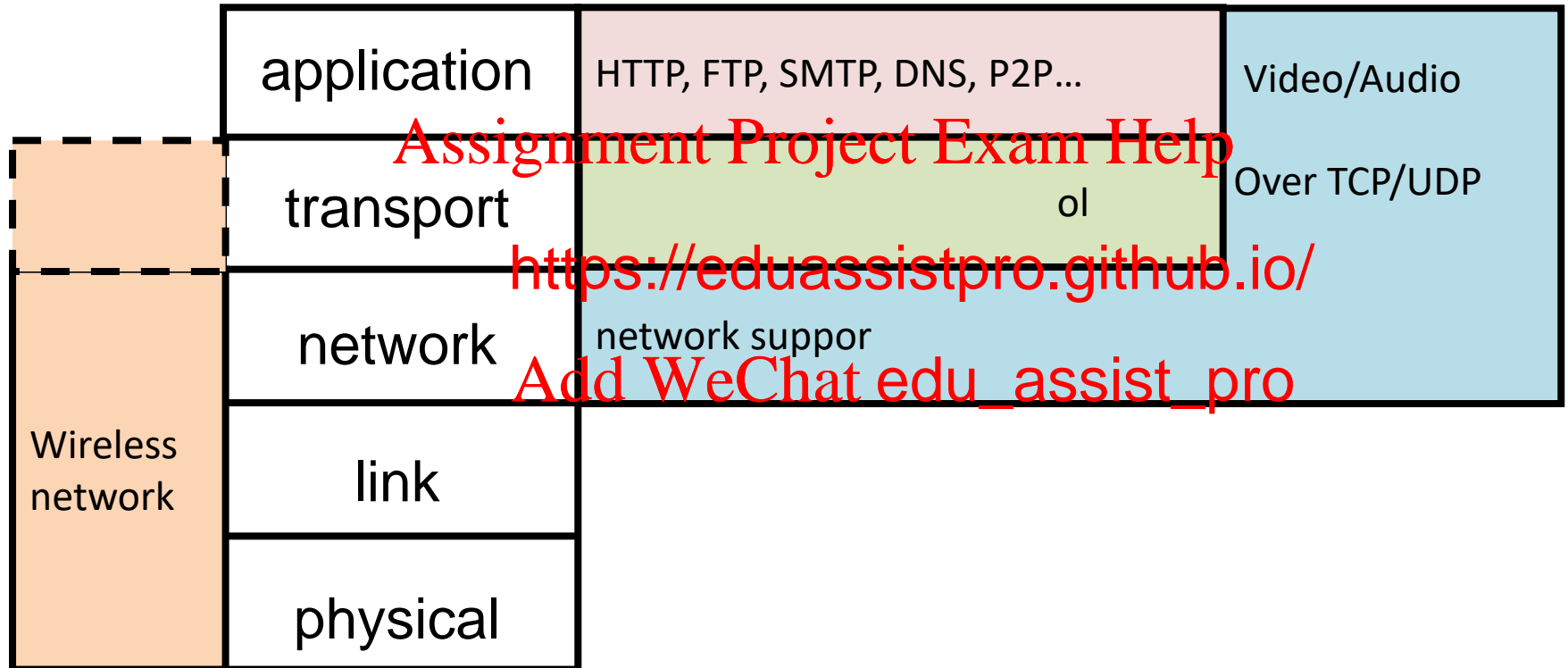
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# Application Layer

Role: support network applications

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application

transport

network

link

physical

Network  
Optimization

Queueing Theor

Principles  
of  
CDMA

Example:  
Game Theory

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Wireshark

application

Socket

transport

network

link

physical

Queue simulator

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# Network analysis example

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# Two users competing for one channel

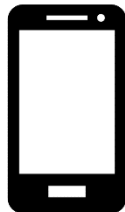
## Assignment Project Exam Help

User 1

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User 2





# Two users competing for one channel

A collision happens! No one is successful!

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User 1

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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 off	5	0
1 off, 2 on	0	5
1 on, 2 on	-5	-5

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## Two users competing for one channel

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

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

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Useful to solve many problems  
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Also useful to analyse computer games on the Internet!  
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Two members of a criminal gang are arrested

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Each prisone

communicat <https://eduassistpro.github.io/>

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Each prisoner can:

1 confess

2 keep silent

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## Result

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Both confes prison

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Both keep silent: both ser n prison

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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	$(-10, 0)$	$(-1, -1)$
Keep silent	$(0, -10)$	$(-1, -1)$

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

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

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

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decision, loss

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



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

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B changes his/decision, WeChat edu\_assist\_pro

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

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

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Not a Nash  
Equilibrium !

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



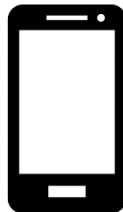
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User 1

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User 2



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

Nash Equilibrium?

<div>1's decision</div> <div>(1, 2) utility</div> <div>2's decision</div>	Transmit	Keep silent
Transmit	<p>0,10)</p>	<p>0,10)</p>
Keep silent	<p>(10,0)</p>	<p>(0,0)</p>

Two Nash Equilibria

<div>1's decision</div> <div>(1, 2) utility</div> <div>2's decision</div>	Transmit	Keep silent
Transmit	<p>0,10)</p>	<p>0,10)</p>
Keep silent	<p>(10,0)</p>	<p>(0,0)</p>

Two Nash Equilibria

This is still not ideal.

Solution: mixed strategy.

Each player c

User 1: trans

keep silent with

User 2: transmit with probability  $p_2$

keep silent with probability  $(1-p_2)$

listic decision!

ty  $p_1$

lity  $(1-p_1)$

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

$$\begin{aligned} & -5 * p1 * p2 + 10 * p1 * (1 - p2) + 0 * (1 - p1) * p2 + 0 * (1 - p1) * (1 - p2) \\ & = -5 * p1 * p2 + 10 * p1 * (1 - p2) \end{aligned}$$



Let's try  $p_2 = 2/3$

User 1's average utility

$$-5 * p_1 * p_2 + 10 *$$

$$= -5 * p_1 * 2/3 + 1$$

$$= 0$$

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No matter how to change  $p_1$ , user 1's utility is 0

Similarly

If  $p_1 = 2/3$

No matter how to change  $p_2$ , user 1's utility is 0

$p_1=p_2=2/3$  is a Nash Equilibrium

Why?

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User 1's average

If  $p_2=2/3$

<https://eduassistpro.github.io/>

No matter how we change  $p_2$ , user 1's utility is 0

If  $p_1=2/3$

No matter how to change  $p_2$ , user 1's utility is 0



# What happens if users are cooperative?

If the users are not selfish

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ion

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$p_1=p_2=1/3$  is

User 1's average utility

User 2's average utility is  $5/3$



## Network performance in summery

Situations	Solution	Utility
Selfish users	$p_1=2/3,$ $p_2=2/3$	(0,0)
Cooperative users	$p_2=1/3$	(5/3)

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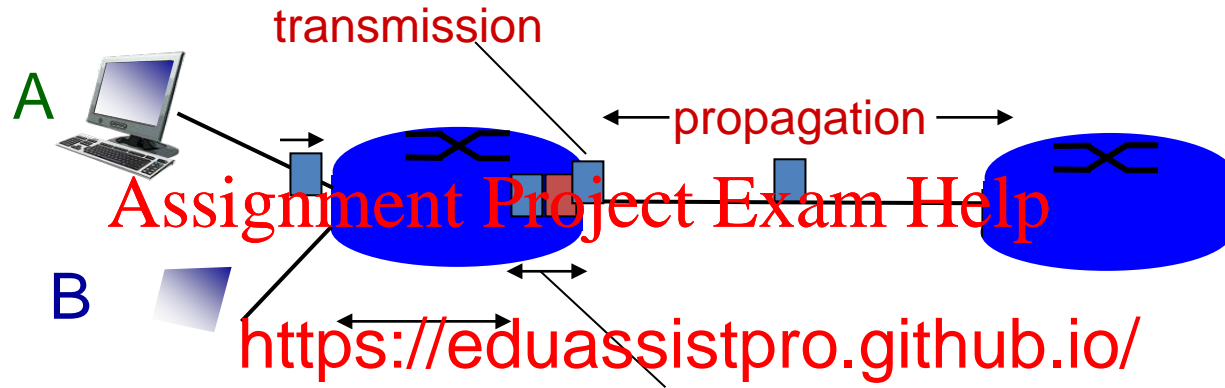
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## Four sources of packet delay



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

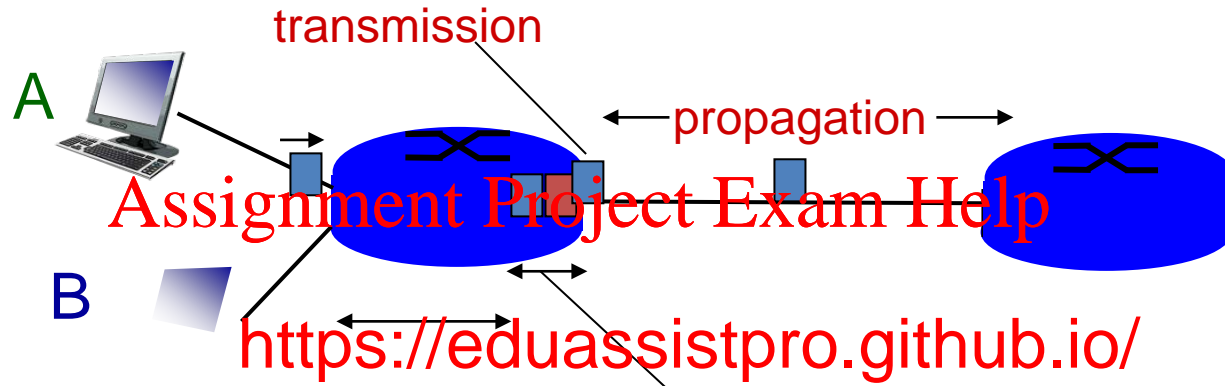
$d_{\text{proc}}$ : nodal processing

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

$d_{\text{queue}}$ : queueing delay

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

## Four sources of packet delay



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

$d_{\text{trans}}$ : transmission delay:

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

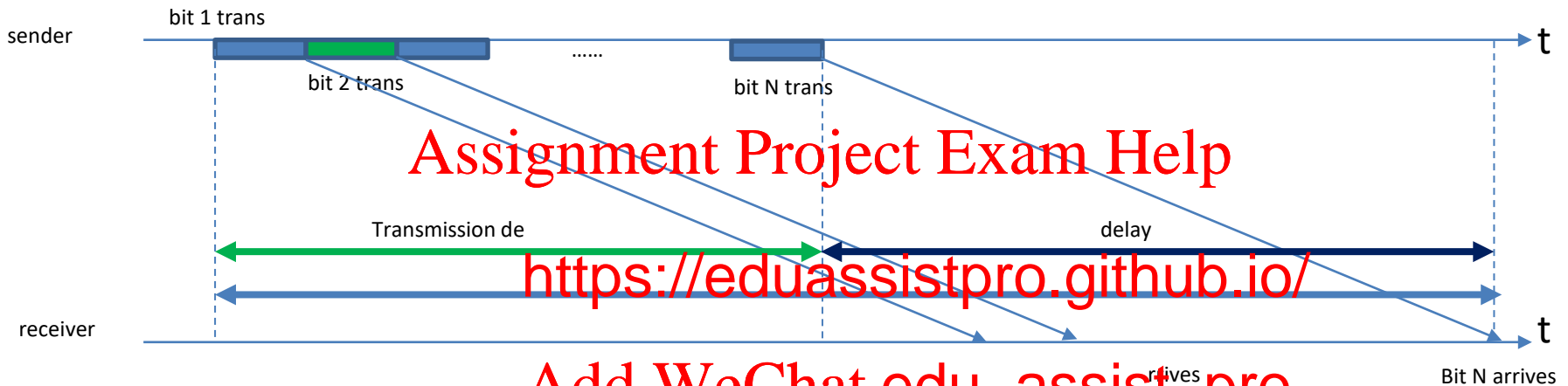
$d_{\text{prop}}$ : propagation delay:

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

$d_{\text{trans}}$  and  $d_{\text{prop}}$   
very different



# Transmission Delay and Propagation Delay



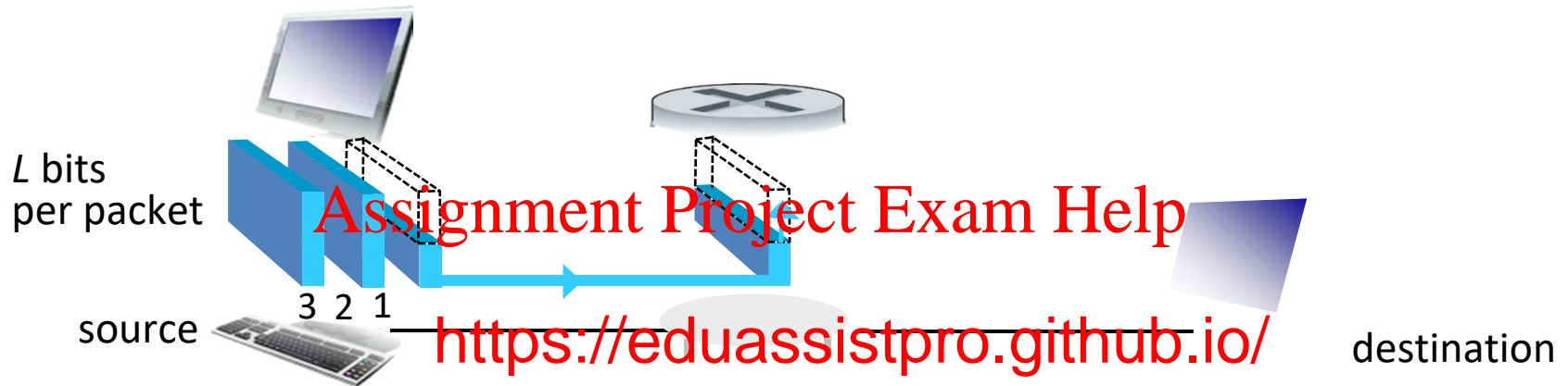
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## Store-and-forward



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- › 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

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

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Add WeChat  $\text{edu\_assist\_pro}$   $\text{ity} = La/R$

- ❖  $La/R \sim 0$ : avg. queueing delay small
- ❖  $La/R < \sim 1$ : avg. queueing delay large
- ❖  $La/R > 1$ : more “work” arriving than can be serviced, average delay infinite!



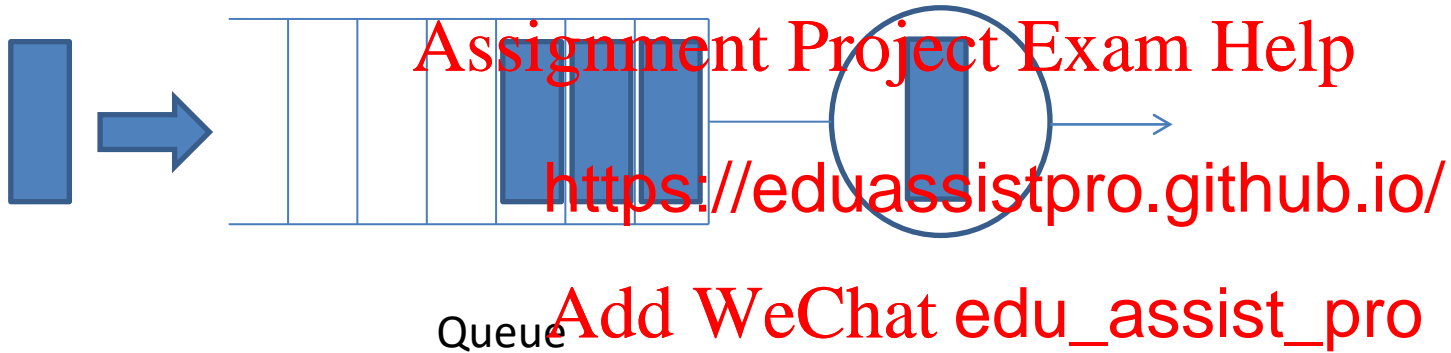
$La/R \sim 0$



$La/R < \sim 1$



# A Brief Discussion on Queueing Theory



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

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## › *Job arrival*

- Poisson process
- Number of arrivals in  $[0, t)$ :  $N(t)$
- Distribution of  $N(t)$

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

## › *Job service time*

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- *Exponential distri*

- PDF: probability <https://eduassistpro.github.io/>

- CDF: Cumulative distribution f [Add WeChat edu\\_assist\\_pro](#)  $e^{-\mu x}$

- Mean:  $1/\mu$

- Can serve  $\mu$  jobs per unit time.

- Service rate:  $\mu$

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- › *Number of servers*

- 1

- › *Queue size*

- Infinity

- › *Service disciplines*

- First in first served

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- › *Conclusions*

- › *Mean waiting time*

- ›  $1/(\mu - \lambda)$

- › *Derivation will be shown later.*

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