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

People

- Wei Bao, *Coordinator and Lecturer*
  - Weeks 1-12
  - Office: J12-4W-425
  - Phone: (02) 8627 4865
  - wei.bao@sydney.edu.au
  - https://www.sydney.edu.au/engineering/about/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 1-12
  - Office: J12-West Wing
  - zhengjie.yang@sydney.edu.au
  - Office hour: by appointment, through Zoom
- Background
  - Research: Networking, mobile computing, distributed machine learning.
  - 3-year experience in tutoring this UoS

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 safe distance from the building and maintain physical distancing whilst waiting until the emergency is over.
- In some circumstances, we might be asked 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 mouth** when **coughing and sneezing** with a tissue or a flexed elbow.
- Maintain a **distance of at least 1.5m** between 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 remotely.
- Make sure you read the information on **special consideration** in the unit outline.

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 classes, especially those involving use of shared equipment, please follow additional advice from your coordinators.
- Please take care of each other and yourselves 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, please switch it on so we can see you!
- If you are speaking to the camera, make 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.

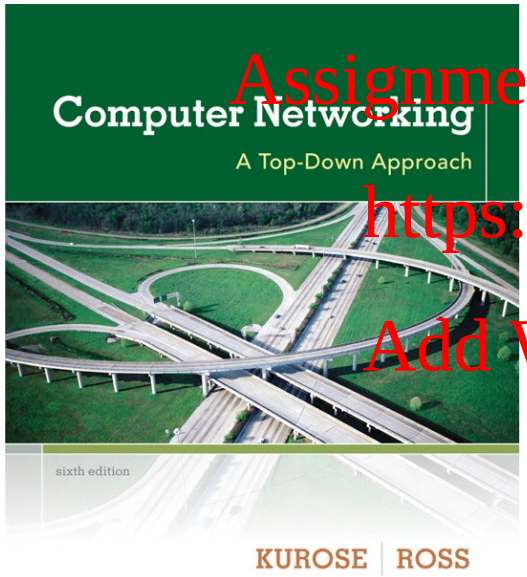
Resources

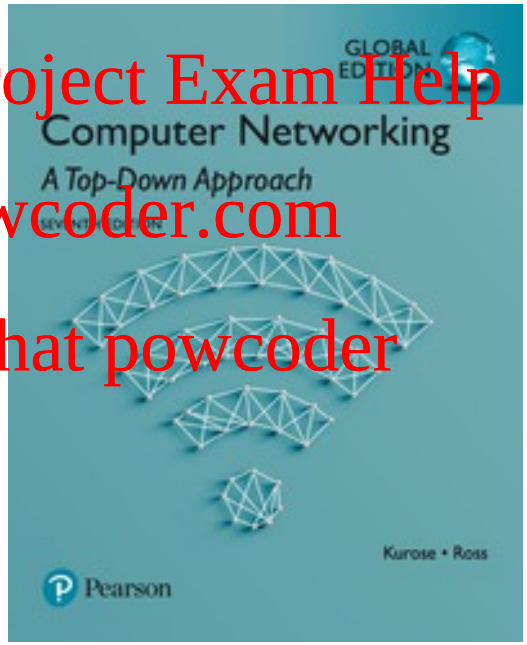
Canvas: https://canvas.sydney.edu.au/

- 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 instructions
- Lecture videos
  - We intend to record the lectures, but the technology 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,





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.

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-assess
- Students are responsible learners
  - Participate in classes constructively
    - Respect for one another (criticize ideas, not people)
    - 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—W5

- W12: Assignment 2, 20%

  Covers W6—W11

- Exam period: Final exam, 60%

  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 for special consideration online, upload scans
  - Note you have only a quite short deadline for applying
  - 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

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, i.e. new mark = 8/10
  - An average assignment that would normally get 5/10 and is 5 days late loses 25% of the full 10 marks, i.e. new mark = 2.5/10
  - Assignments more than 10 days late get 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.

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 dishonest or unfair means.
  - Plagiarism means presenting another person's work as one's own work by presenting, copying or reproducing it without appropriate 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

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Assessment design and risks

Assessment types, risks and mitigating strategies

The Academic Honesty in Coursework Policy 2015 requires that we review and renew assessments to eliminate or minimise opportunities for students to gain unfair advantage through plagiarism or academic dishonesty.

You should review the assessment each time a unit is offered, including redesigning assessment tasks to prevent any breaches of academic integrity from reoccurring and assessment tasks should not be reused in a way that would give some students an advantage or could be exploited for advantage.

The Academic Honesty Procedures 2016 outline the steps unit coordinators should take when evaluating the risks to the integrity of assessment.

Schedule One of the Procedures also provides a Summary of Assessment Types, Risks and Mitigating Strategies and a risk assessment matrix developed by the Academic Board, which is provided here as an MS Word template: risk assessment matrix template (DOCX, 32k).

The use of Turnitin for the submission of all text-based written assignments is also mandatory. With the approval of the Deputy Vice-Chancellor (Education) other similarity detecting software may be used for other types of assessments. Where similarity detection software is used, it must also be declared in your unit of study outline.

Part 1 of the Taskforce report includes discussion of good practice for Assessment (section 2.3) and Exams (section 2.4) as well, and is available for download from the educational integrity homepage.

Report an incident >

Advice and support

Office of Educational Integrity

T +61 2 862 **75221**

T +61 2 862 **75171**

E educational.integrity@sydney.edu.au

Faculty contacts

See the contact information page for your faculty's educational integrity team

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 see include:

anxiety, arthritis, asthma, asperger's disorder, ADHD, bipolar disorder, broken bones, cancer, cerebral palsy, chronic fatigue syndrome, crohn's disease, cystic fibrosis, depression, diabetes, dyslexia, epilepsy, hearing impairment, learning disability, mobility impairment, multiple sclerosis, post traumatic stress, schizophrenia , 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/study/academic-support/support-for-international-students.html

Aboriginal and Torres Strait Islanders

http://sydney.edu.au/study/academic-support/aboriginal-and-torres-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 assessment task relates to these

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

COMP5416: Advanced Network Technologies

The unit introduces networking concepts beyond the best effort service of the core TCP/IP protocol suite. Understanding of the fundamental issues in building an integrated multi-service network for global Internet services, taking into account service objectives, application characteristics and needs and network mechanisms will be discussed. Enables students to understand the core issues and be aware of proposed solutions so they can actively follow and participate in the development of the Internet beyond the basic bit transport service.

Details | Enrolment rules | Learning outcomes

Code	COMP5416
Academic unit	Computer Science
Credit points	6

Enrol now

Current students can enrol in Sydney Student

→

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. Network science: Network optimization*
12. Recent advances in Network*, Review

1. T: Basic network performance analysis
2. L: Wireshark, HTTP packet sniffing
3. L: Python socket programming
4. T: Math for network analysis
5. T: Transport layer and TCP
6. L: Network and queue simulator
7. T: Multimedia network
8. L: Real-time protocol
9. T: Scheduling and Queues
10. L: Network programming
11. T: Wireless and noise
12. 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 problems

› Why is math important?

Practice

› Labs: will require programming

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

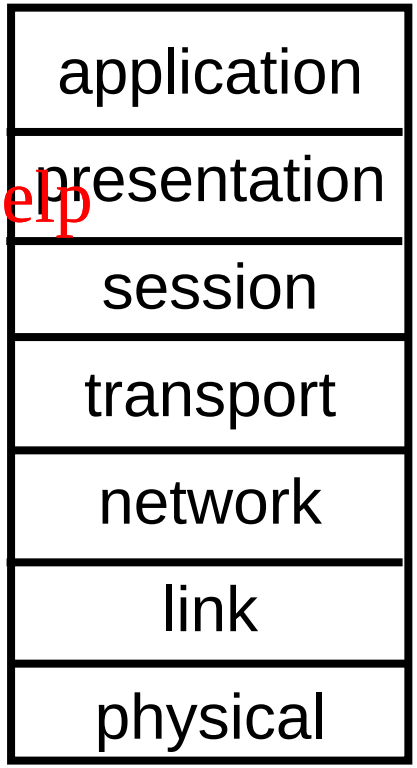
You should be fine if you know Java/C

› Wireshark experiment

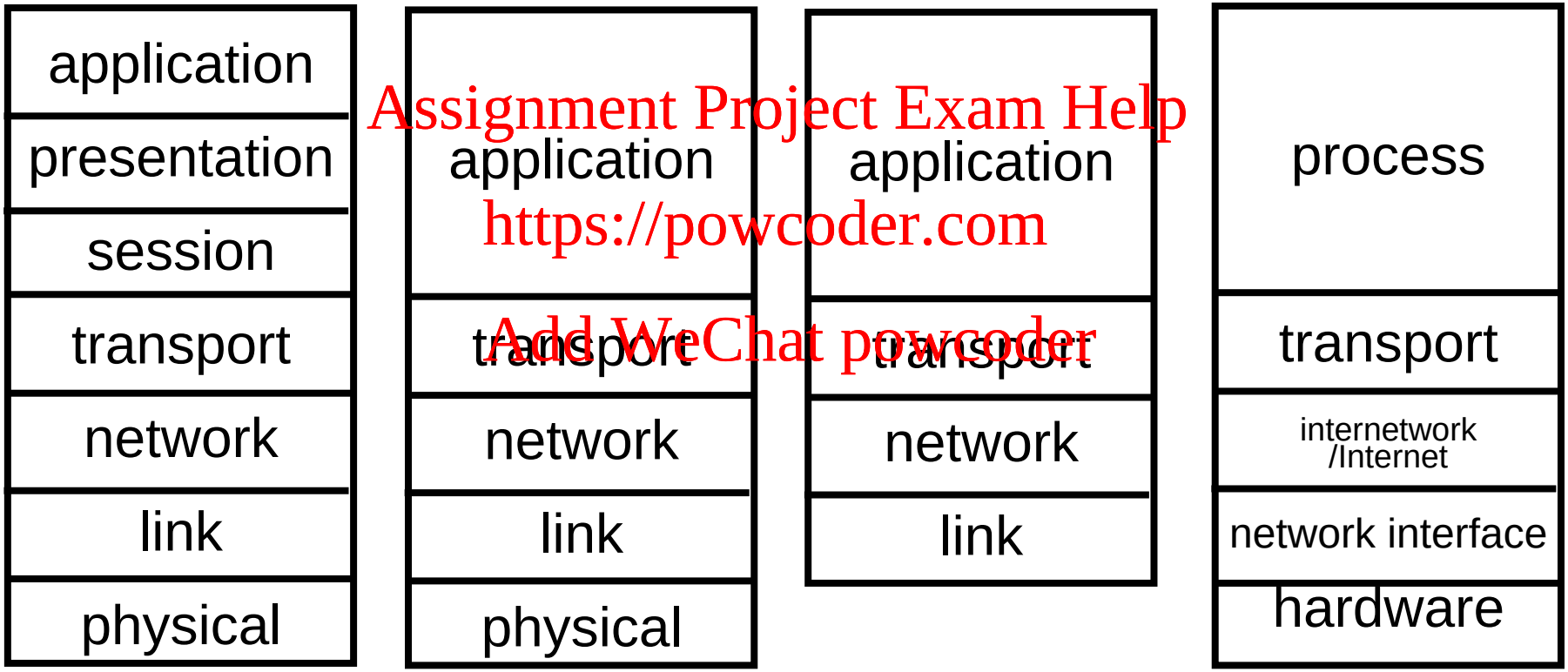
Layered Network

ISO/OSI model

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



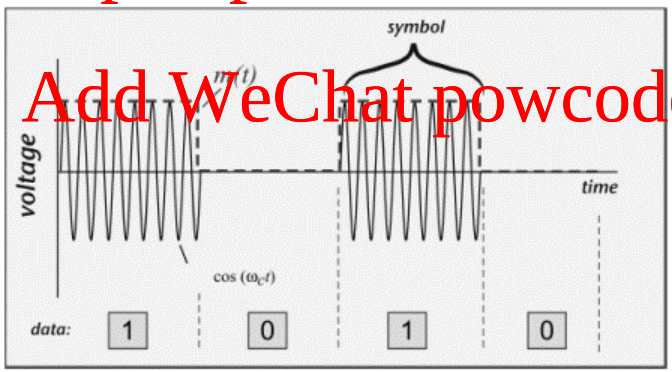
Network Layers



Network Layers

How to provide network applications satisfies users?	Application
How to provide end-to-end connections for programs running at different devices in the network?	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

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:

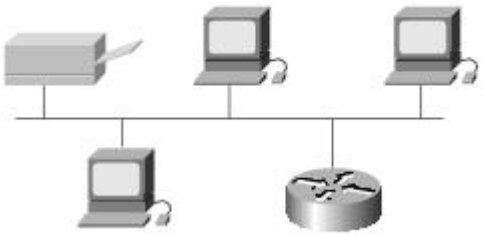
Sender 010101, receiver 010100

Medium access control:

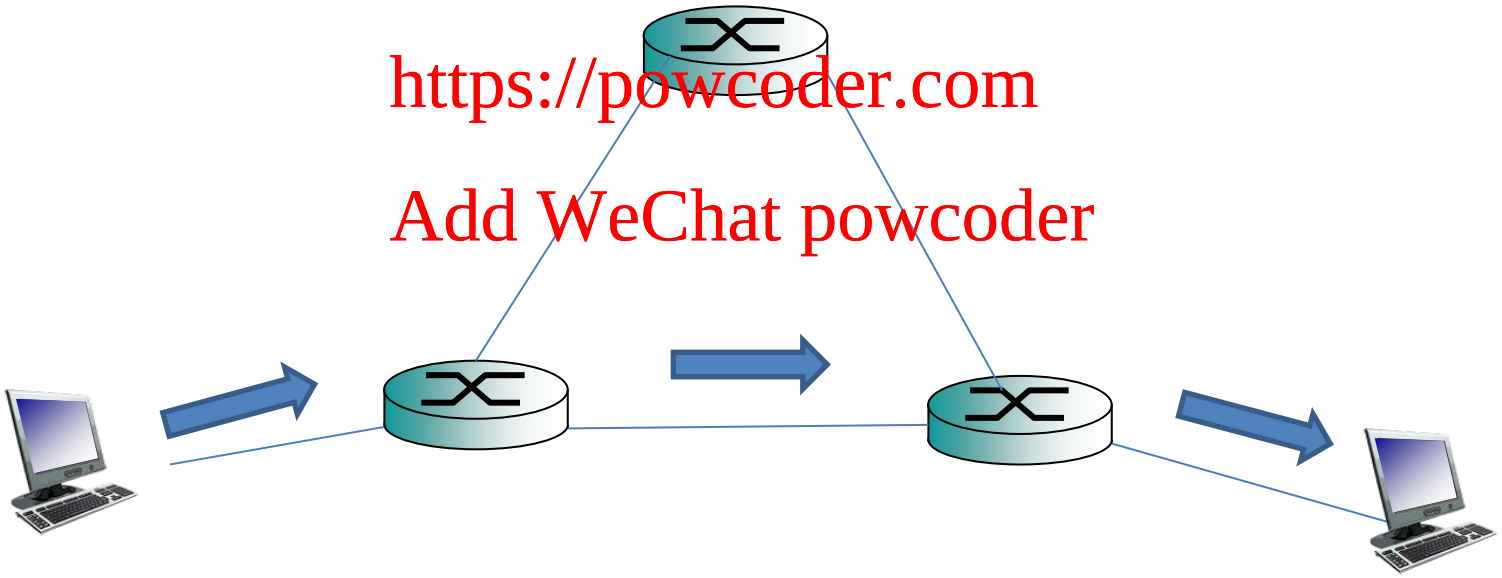
Two devices talking at the same time?

Link-layer addressing:

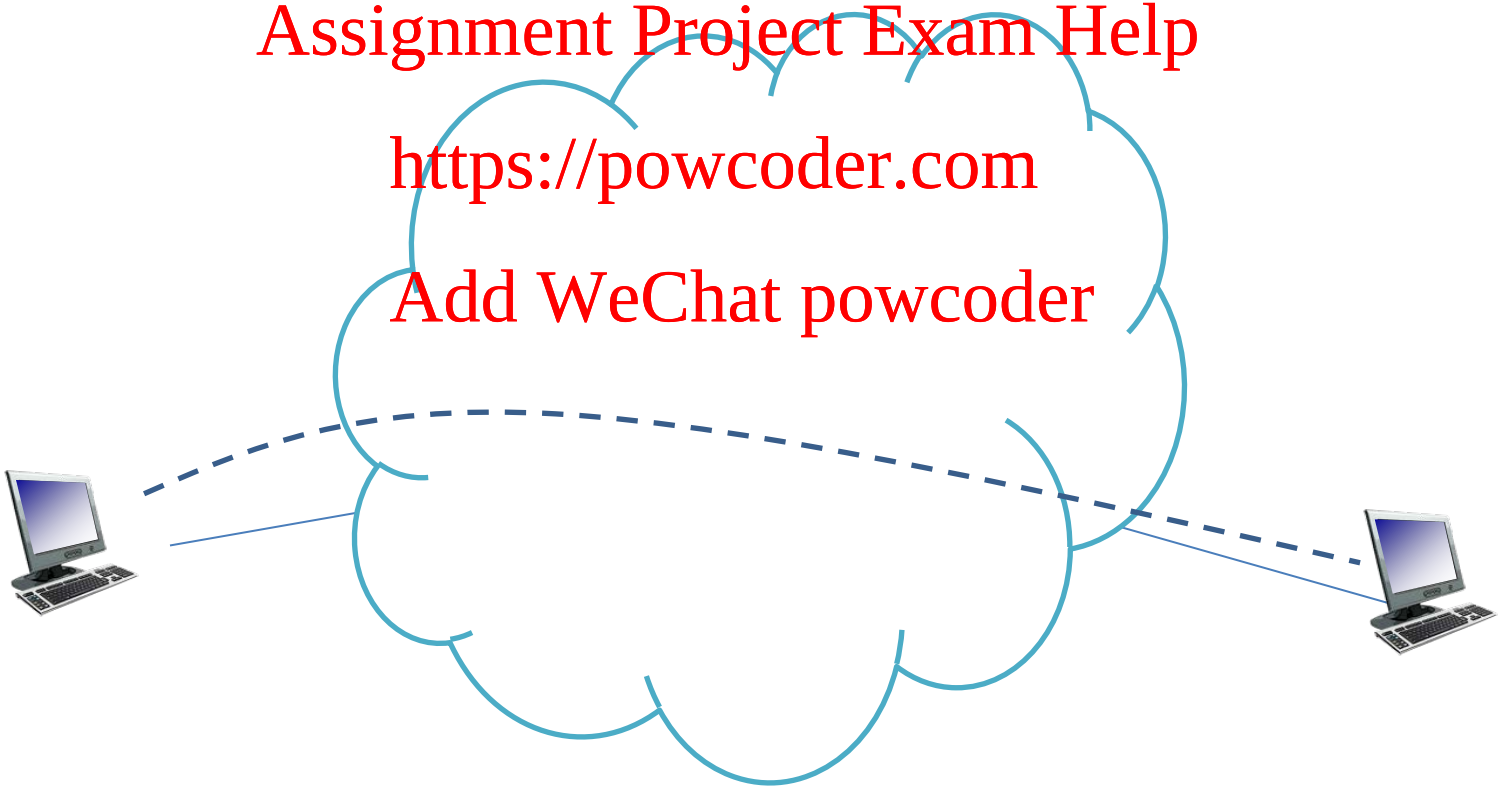
This information is for you.



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

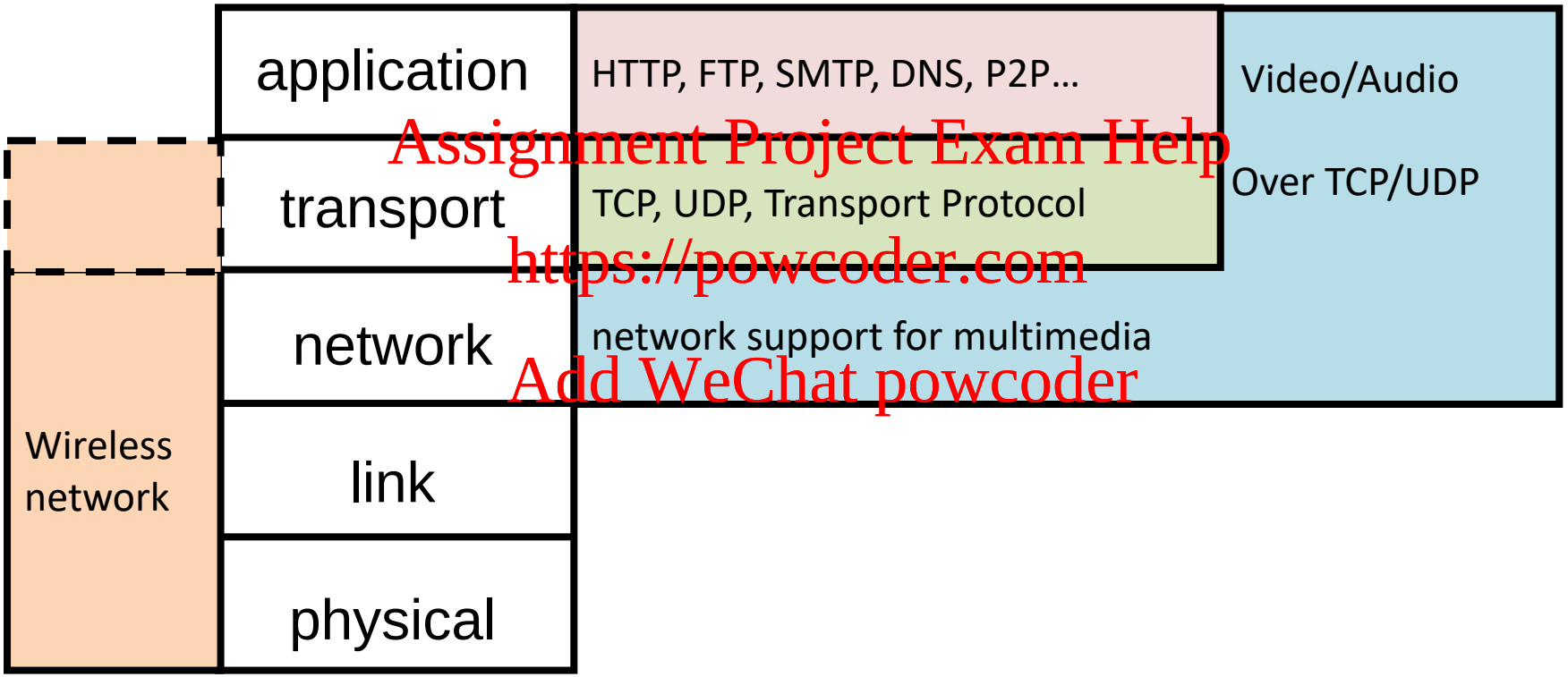


Role: manage program-program (process-process) data transfer

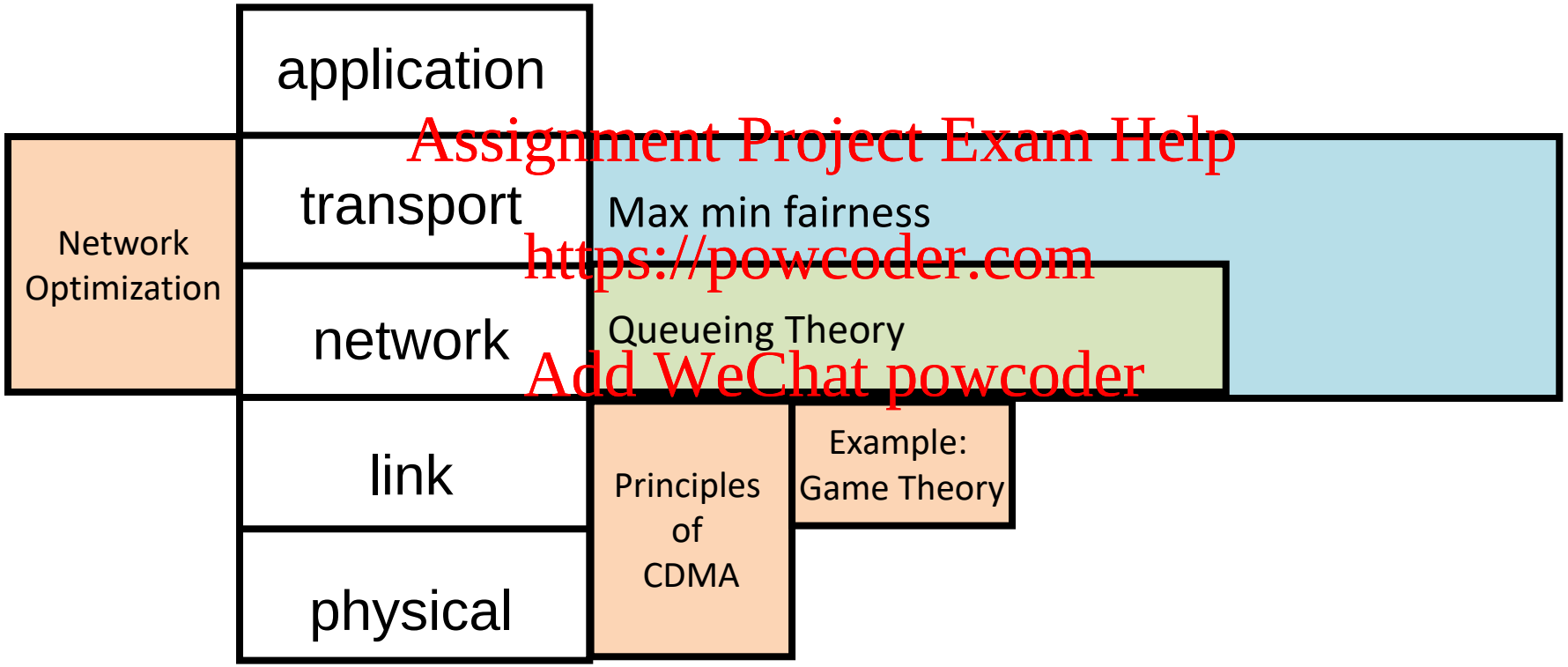


Role: support network applications

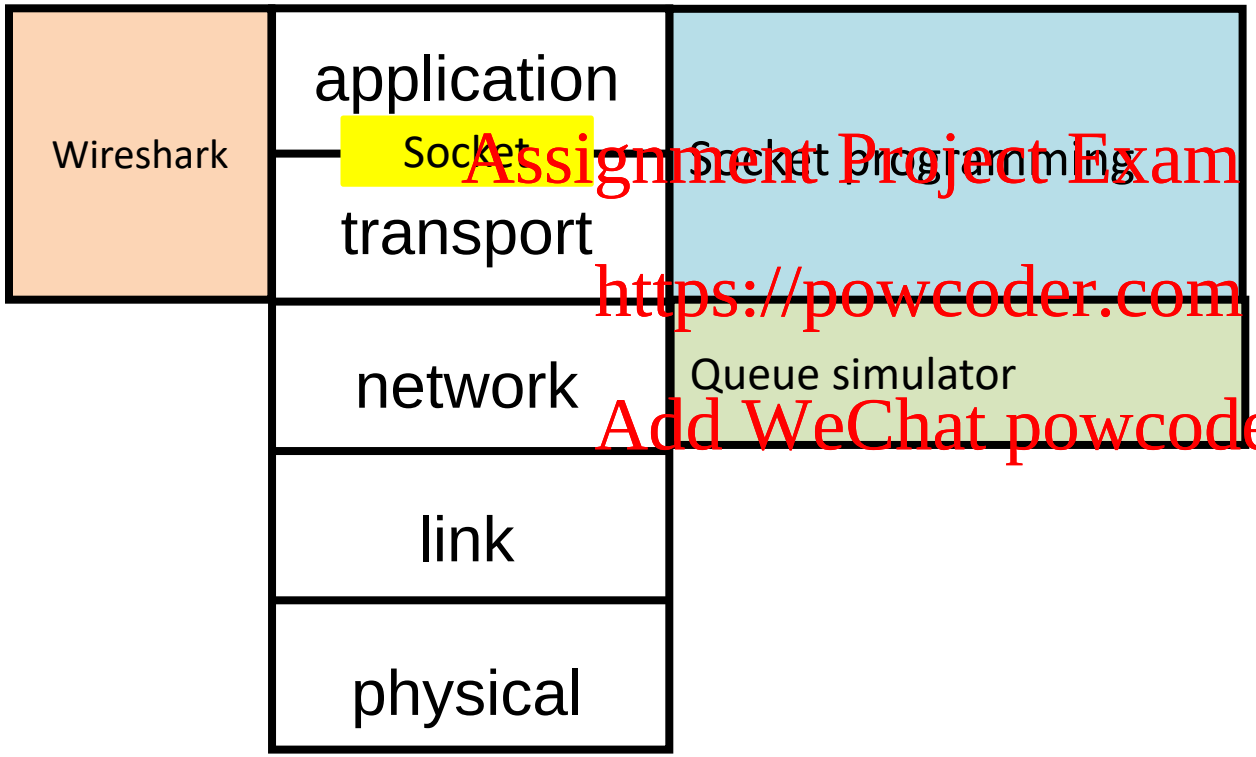
Preview: Practice



Preview: Theory



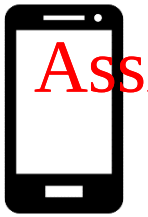
Preview: Programming/Experiment



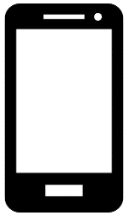
Network analysis example

Two users competing for one channel

User 1

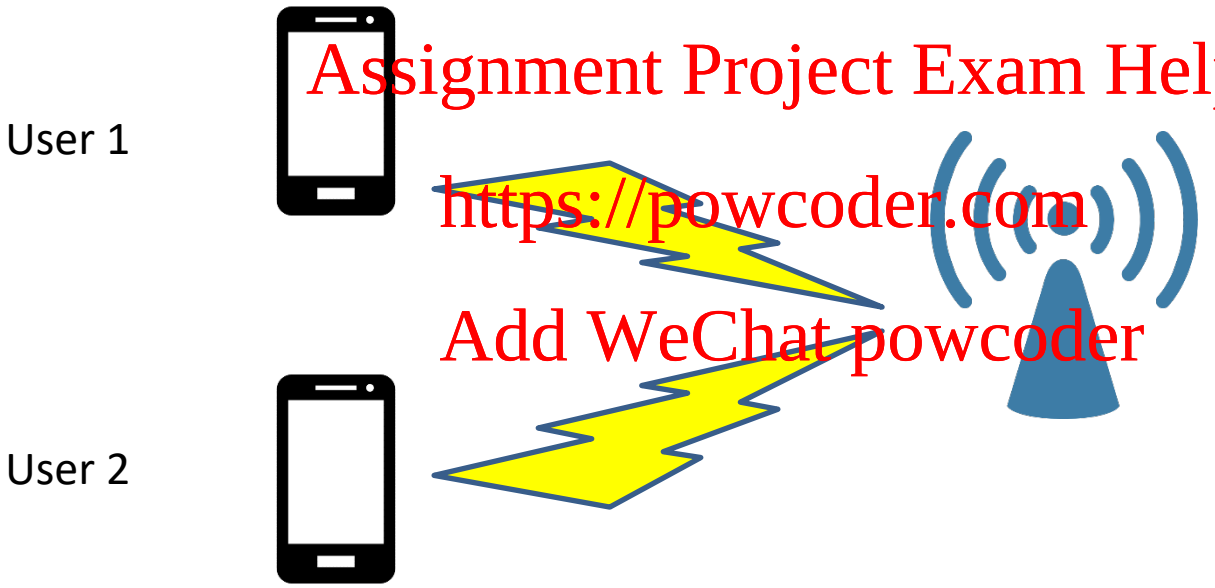


User 2



Two users competing for one channel

A collision happens! No one is successful!



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	10	0
1 off, 2 on	0	10
1 on, 2 on	-5	-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 off	10	0
1 off, 2 on	0	10
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	10	0
1 off, 2 on	0	10
1 on, 2 on	-5	-5

Solution: Game Theory!

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

Useful to solve many economical problems!

Also useful to analyse computer networks and the Internet!

Prisoner's dilemma

Two members of a criminal gang are arrested

Each prisoner has no means of communicating with the other

Each prisoner can:

1 confess

2 keep silent

Prisoner's dilemma

Result

Both confess: both serve 5 years in prison

Both keep silent: both serve 1 year in 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	(-5,-5)	(-10,0)
Keep silent	(0,-10)	(-1,-1)

Nash Equilibrium

A's decision / (A, B) utility / B's decision	Confess	Keep silent
Confess	(-5,-5)	(-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

A's decision / (A, B) utility / B's decision	Confess	Keep silent
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Nash Equilibrium

A's decision / (A, B) utility / B's decision	Confess	Keep silent
Confess	(-5,-5)	(-10,0)
Keep silent	(0,-10)	(-1,-1)

B changes his/decision, loss

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

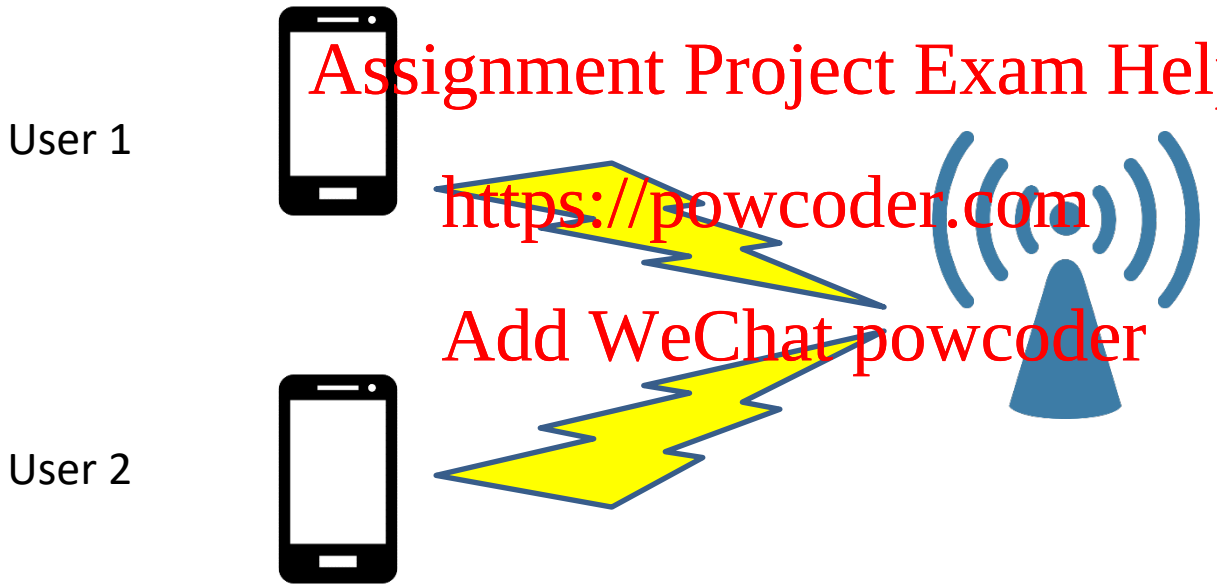
Nash Equilibrium

A's decision / (A, B) utility / B's decision	Confess	Keep silent
Confess	(-5,-5)	(-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



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Back to our problem

1's decision / (1, 2) utility / 2's decision	Transmit	Keep silent
Transmit	(-5,-5)	(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	(-5,-5)	(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	(-5,-5)	(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 can make probabilistic decision!

User 1: transmit with probability p1

keep silent with probability (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	(-5,-5) p1*p2	(0,10) (1-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*p1*(1-p2)

=-5*p1*2/3+10*p1*1/3

=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 average utility

If p2=2/3

No matter how to change p1, user 1'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 the optimal solution

User 1's average utility is 5/3

User 2's average utility is 5/3

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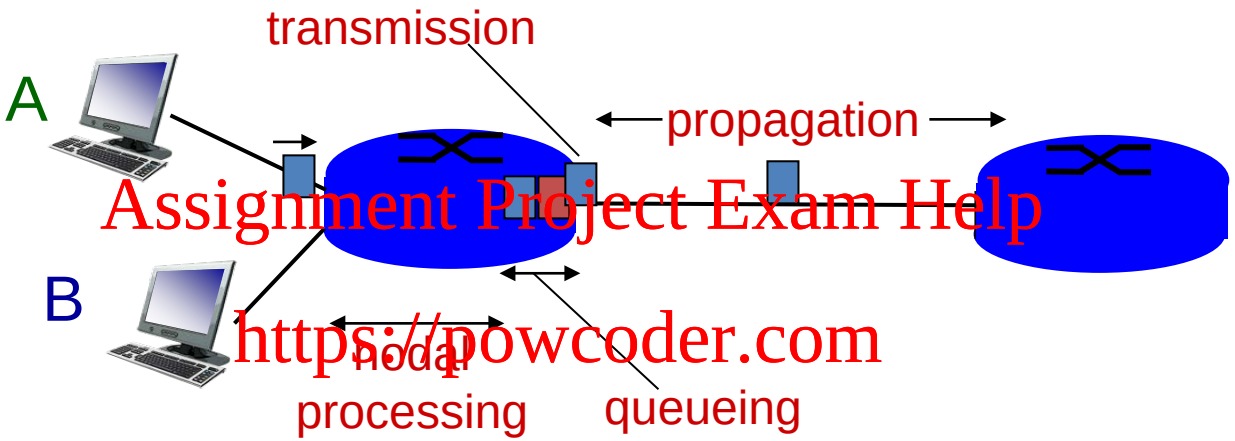
Network performance in summery

Situations	Solution	Utility
Selfish users	p1=2/3, p2=2/3	(0,0)
Cooperative users	p1=1/3 p2=1/3	(5/3,5/3)

Delays

Delay

Four sources of packet delay



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

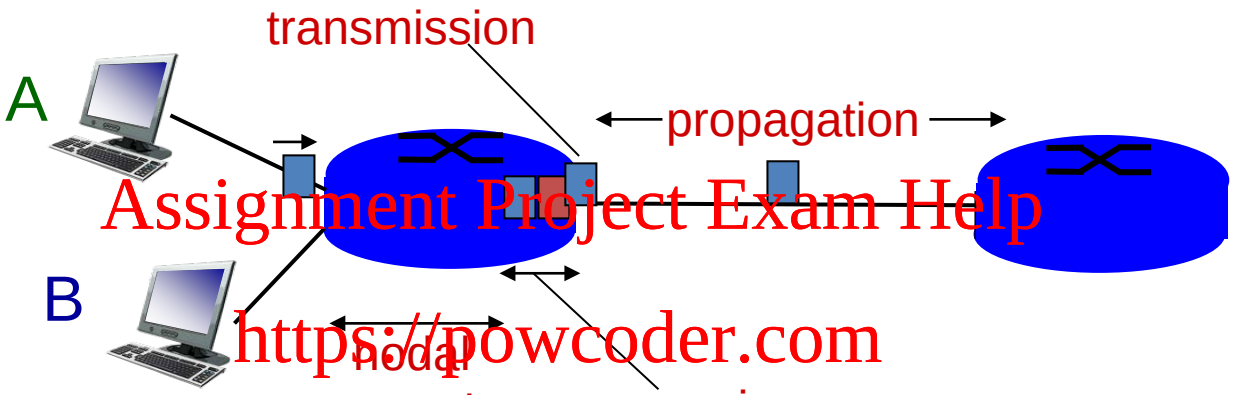
d_{proc}: nodal processing

- 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

Four sources of packet delay



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

d_{trans}: transmission delay:

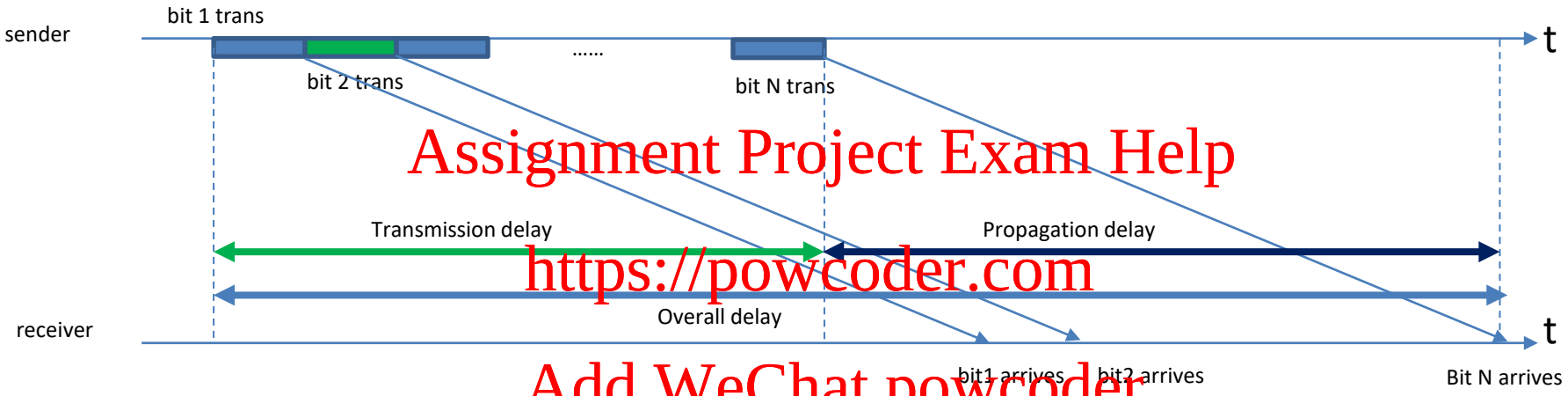
- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{prop}: propagation delay:

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

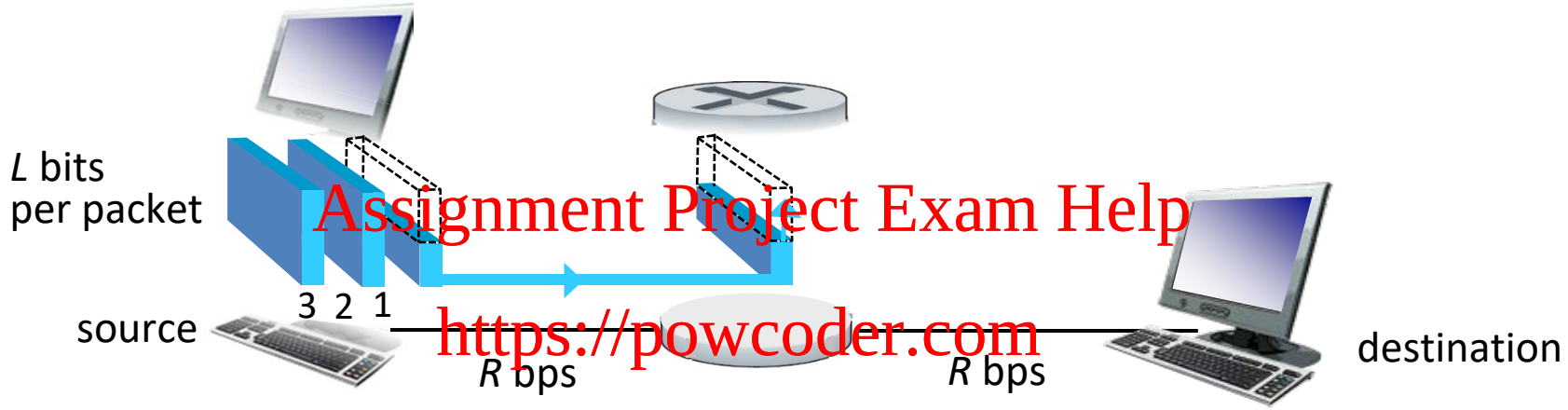
d_{trans} and d_{prop} *very* different

Transmission Delay and Propagation Delay



Store and Forward

Store-and-forward

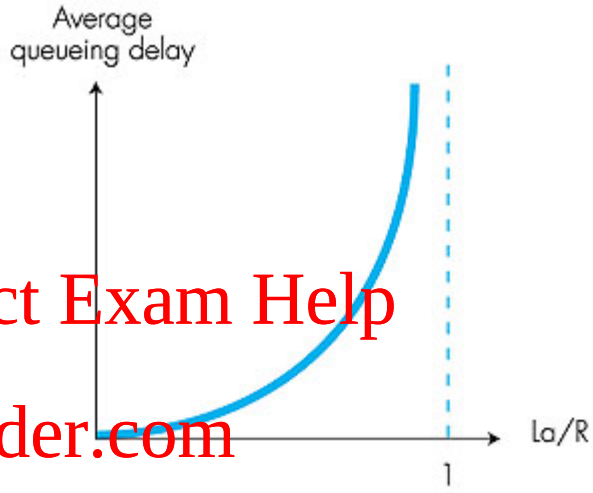


- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- *end-end delay:* 2 *L*/*R* (assuming zero propagation delay)

- *one-hop numerical 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 arrival rate



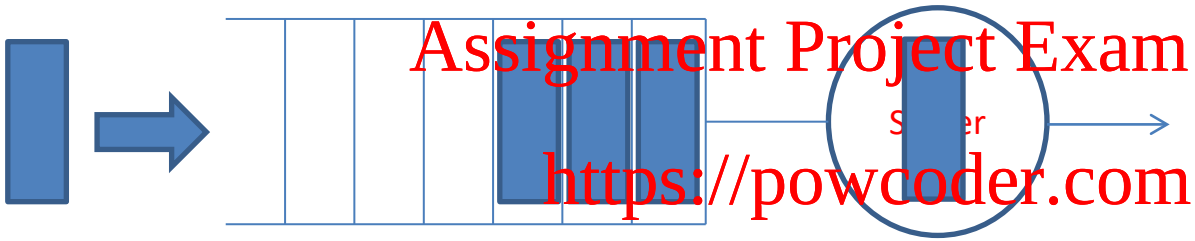
traffic intensity = La/R

- *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



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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 in [0, t): N(t)
  - Distribution of N(t):

$$P\{N(t) = n\} = \frac{(\lambda t)^n}{n!} e^{-\lambda t}.$$

  - Mean: E(N(t))= λt
  - Arrival rate λ

Properties of a Queue

- *Job service time*

  - *Exponential distribution, with mean of 1/μ*
  - PDF: probability density function $\mu e^{-\mu x}$
  - CDF: Cumulative distribution function $1 - e^{-\mu x}$
  - Mean: $1/\mu$
  - Can serve μ jobs per unit time.
  - Service rate: μ

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Properties of a Queue

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

Properties of a Queue

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