Deadlocks

- What is deadlock & how it occurs
- Detecting potential deadlocks
  - resource allocation graphs
- Recovery techniques
- Prevention techniques
- Livelock and starvation

Deadlocks

Example: two processes want to scan a document, and then save it on a CD

P0

```
down(scanner);
down(cd_writer);
scan_and_record();
up(cd_writer);
up(scanner);
```

```
writer);
anner);
scan_and_record();
up(scanner);
up(cd_writer);
```

Deadlock?

Dining Philosophers

Each philosopher needs 2 chopsticks in order to eat

Dining Philosophers

Does this work?

What if everybody takes chopstick[i] at same time?

Deadlock

Set of processes is deadlocked if each process is **waiting for an event** that only **another process** can cause

Resource deadlock is most common, 4 conditions must hold:

1. **Mutual e** e is either available or assign s
2. **Hold and wait:** proces st resources while it holds other resources, arlier
3. **No preemption:** resources given to a process cannot be forcibly revoked
4. **Circular wait:** two or more processes in a circular chain, each waiting for a resource held by the next process

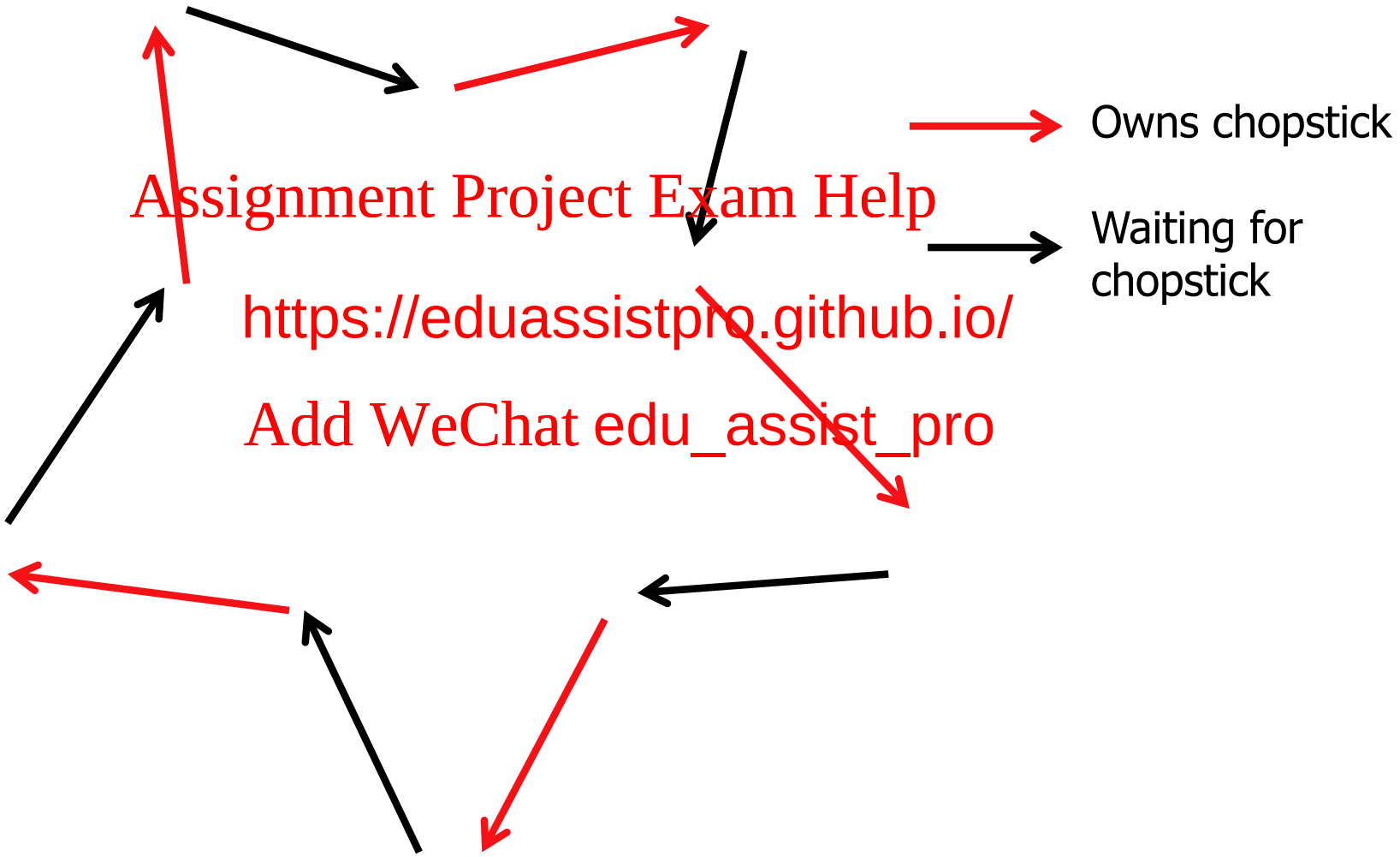
Resource Allocation Graphs

Directed graph models resource allocation

- Directed arc from resource to process means that the process is currently owning that resource
- Directed ar ce means that the process is for that resource

Cycle = deadlock

Dining Philosophers – Deadlock Cycle



Strategies For Dealing With Deadlock

Ignore it

- "The Ostrich Algorithm"
- Contention for resources is low → deadlocks infrequent

Detection and recovery

Dynamic avoidanc allocation

Prevention by neg ions

Detection and Recovery

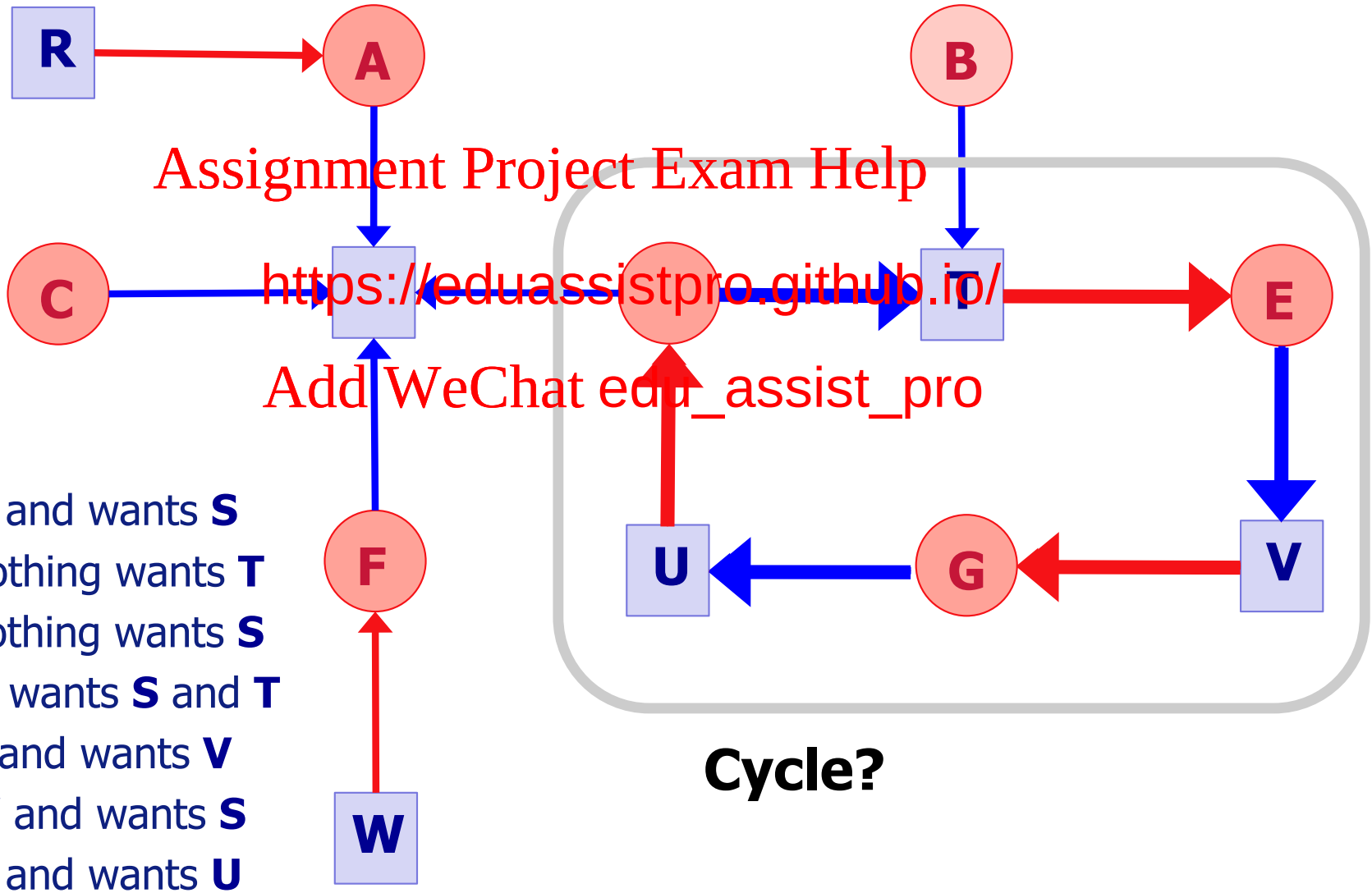
Detects deadlock and recovers ***after the fact***
Dynamically builds resource ownership graph and looks for cycles
When an ***arc*** has been inspected it is marked and not visited again

1. For each node do:
2. Initialise **L** to the
3. Add the current n
   appears in **L** two times. Yes: cycle
4. From current node check if any unm
   outgoing arc
   Yes: goto **5**, No: goto **6**
5. Pick unmarked outgoing arc, mark it, follow it to new current node and goto **3**
6. If this is initial node then no cycles detected, terminate
   else reached dead end, remove it, go back to previous node and make it current and goto **3**

We are doing a depth-first search from each node in the graph, checking for cycles.

[Tanenbaum, MOS 6.4.1]

Detection – Example

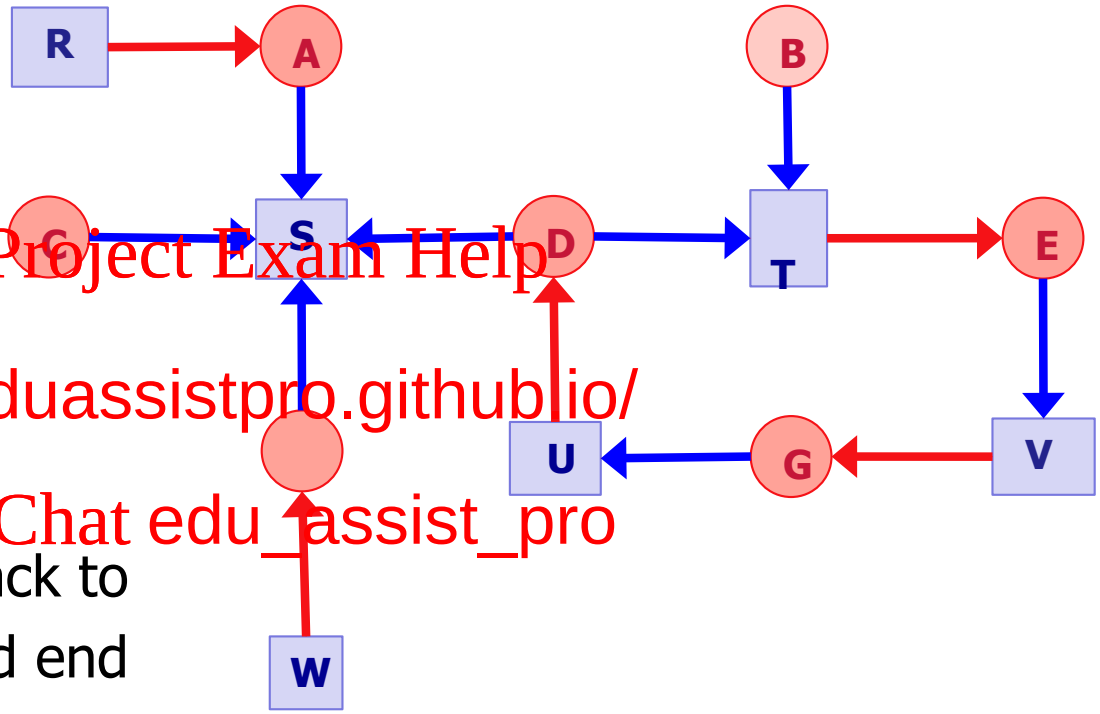


- **A** holds **R** and wants **S**
- **B** holds nothing wants **T**
- **C** holds nothing wants **S**
- **D** holds **U** wants **S** and **T**
- **E** holds **T** and wants **V**
- **F** holds **W** and wants **S**
- **G** holds **V** and wants **U**

Cycle?

Detection – Example (2)

- Starting at **R**, initialise **L** = [ ]
- Add **R** to list and move to **A** (only possibility)
- Add A giving **L = [R,A]**
- Go to S so **L = [R,A,**
- **S** has not outgoing a backtrack to **A**
- **A** has no outgoing arcs, backtrack to
- Restart at **A**, add A to ***L*** → dead end
- Restart at **B**, follow outgoing arcs until **D**, now **L = [B,T,E,V,G,U,D]**
- Make random choice:
  - **S** → dead end and backtrack to **D**
  - Pick T update **L = [B,T,E,V,G,U,D,T]**
- Cycle: Deadlock found, STOP



Recovery

Pre-emption:

- Temporarily take resource from owner and give to another

Rollback:

- Processes are periodically **nted** (memory image, state)

- On a deadlock, **roll back** to previous state

Killing processes:

- Select random process in cycle and kill it!
  - OK for compile jobs, not so good for database, why?

Circular Chain Deadlock Question

Suppose that there is a resource deadlock in a system. Can the set of processes deadlocked include processes that are not in the circular chain in the corresponding resource allocation graph?

Strategies For Dealing With Deadlock

Ignore it

Detection and recovery

Dynamic avoidance

- System grants resources when it knows that it is safe to do so

Prevention

Banker's Algorithm (Dijkstra 1965)

- Four customers A, B, C and D
  - Credit unit = £1K
- Each customer randomly asks for credit
- For each process A-D,
  - Has = number of resource items allocated
  - Max = number of items required.

all customers don't
instead of 22) units

Banker's Algorithm – Save vs. Unsafe States

SAFE **UNSAFE**

Safe state:

- Are there enough resources to satisfy ***any*** (maximum) request from some customer?
- Assume that customer repays loan, and then check next customer closest to the limit, etc.

A state is **safe** iff there exists a sequence of allocations that *guarantees* that all customers can be satisfied

Banker's Algorithm – Safe vs. Unsafe States

SAFE

UNSAFE

A state is **safe** iff there exists a sequence of allocations that *guarantees* all customers can be satisfied

Banker's Algorithm – Safe vs. Unsafe States

Request granted only if it leads to a safe state

Unsafe state does not have to lead to deadlock, but banker cannot rely on this behaviour

Algorithm can be generalized to handle multiple resource types

Bankers Algorithm Question

A system has 12 magnetic tape drives and 3 processes : P0, P1, and P2.

Process	Has	Max Need
P0	5	10
P1	2	
P2	2	

What is a safe sequence for running the processes?

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Strategies For Dealing With Deadlock

Ignore it

Detection and recovery

Dynamic avoidance

Prevention

- *Attack one of* *tions:*
  - *Mutual excl*
  - *Hold and wait*
  - *No preemption*
  - *Circular wait*

Deadlock Prevention

Attacking the Mutual Exclusion Condition

- E.g., share the resource

Attacking the Hold and Wait Condition

- Require all processes to request resources before start
  - If not all available then wait
- Issue: nee d in advance

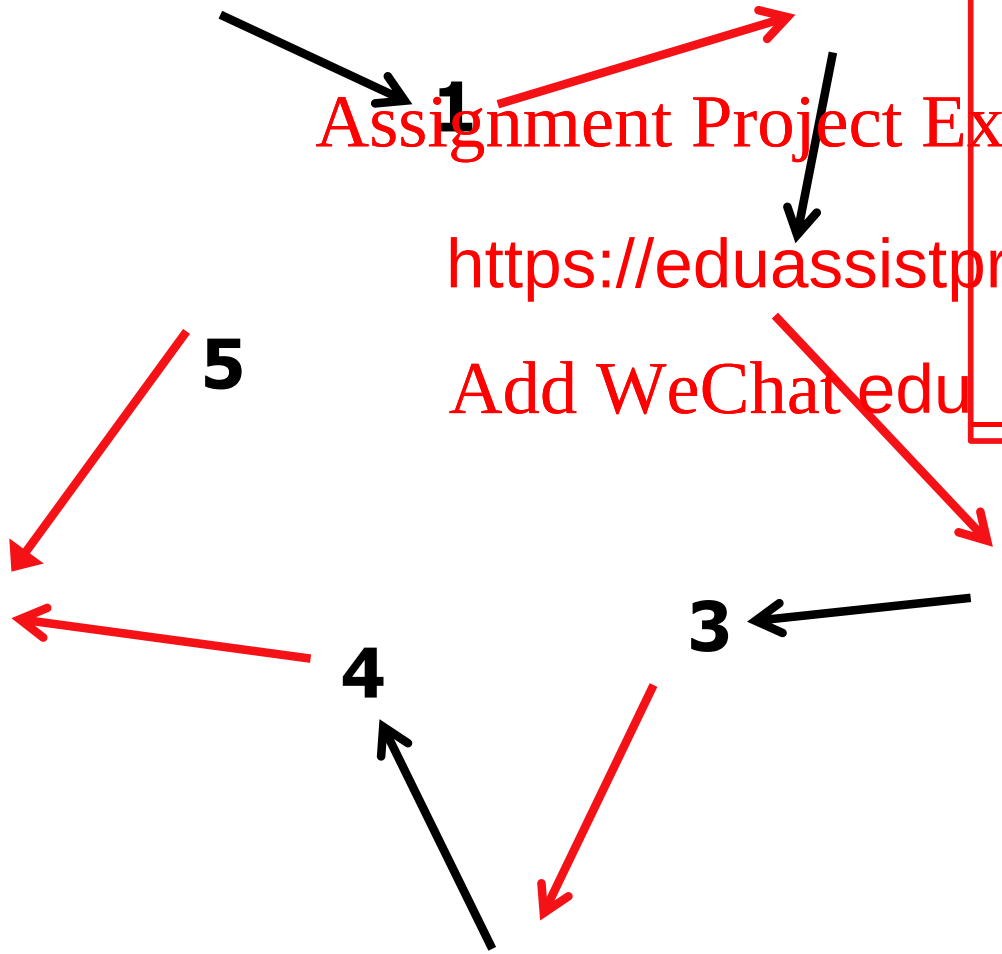
Attacking the No

- E.g., forcing a process to give way through. Usually not good

Attacking Circular Wait Problem

- Force single resource per process, if needs second, must release first.
  - Optimality issues
- Number resources, processes must ask for resources in this order
  - Issue: large number of resources…can be difficult to organise

Dining Philosophers – Ordering Resources



- Request resources in specific order
- Philosopher gets chopstick 4 and can then ask for 5, but if he gets 5 first he cannot ask for chopstick 4.
  e process holding the ghest resource will never ask resource already held.

Communication Deadlock

E.g., process **A** sends message to **B** and blocks waiting on **B's** reply

B didn't get **A'** ocked and **B** is blocked waiting !

Ordering resources, careful scheduling not useful here

What should we use?

- Communication protocol based on timeouts

Livelock

- **Livelock**: Processes/threads are not blocked, but they or the system as a whole does not make progress

- Example 1: `Enter_region()` tests mutex then either grabs resource or reports failure. If attempt fails, it tries again. Processes loop after gaining first resource but failing second.


```
process_A                          process_B
{                                  {
   Enter_region (resource1)           Enter_region (resource2)
   Enter_region (resource2)           Enter_region (resource1)
   Use(resource1, resource2)          Use(resource1, resource2)
   Leave_region (resource2)           Leave_region (resource1)
   Leave_region (resource1)           Leave_region (resource2)
}                                  }
```

- Example 2: System receiving and processing incoming messages. Processing thread has lower priority and never gets a chance to run under high load (**receive livelock**)

Starvation

Concerns policy

Who gets what resource when

Many jobs wan

- Smallest fil maround, but what about occasional lar
- FCFS is more fair in this c

Single Processor Deadlock?

Can a single-processor system have no processes ready and no process running?
Is this a deadlocked system? Explain your answer.

Deadlock Question

Two processes, A and B, each need three records, 1, 2, and 3, in a database. If A asks for them in the order 1, 2, 3, and B asks for them in the same order, deadlock is not possible. However, if B asks for them in the order 3, 2, 1, then deadlock is possible. With three resources, there are 3! = 6 possible co ss can request resources.

What fraction of all combination ed to be deadlock free?

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Deadlock Summary

Deadlocks occur from:

- Accessing limited resources – not enough to go round
- Incorrect programming of synchronisation

Resource allocation graphs can detect potential cyclic deadlock

Recovery: pre-em ess

Prevention

- Use safe resource allocation s
- Avoid unnecessary mutual exclusion – share instead
- Ordered resource allocation

Livelock: no progress – incorrect programming?

Starvation: often due to priority