A Resource Minimizing Scheduling Algorithm with Ensuring the Deadline and Reliability in Heterogeneous Systems

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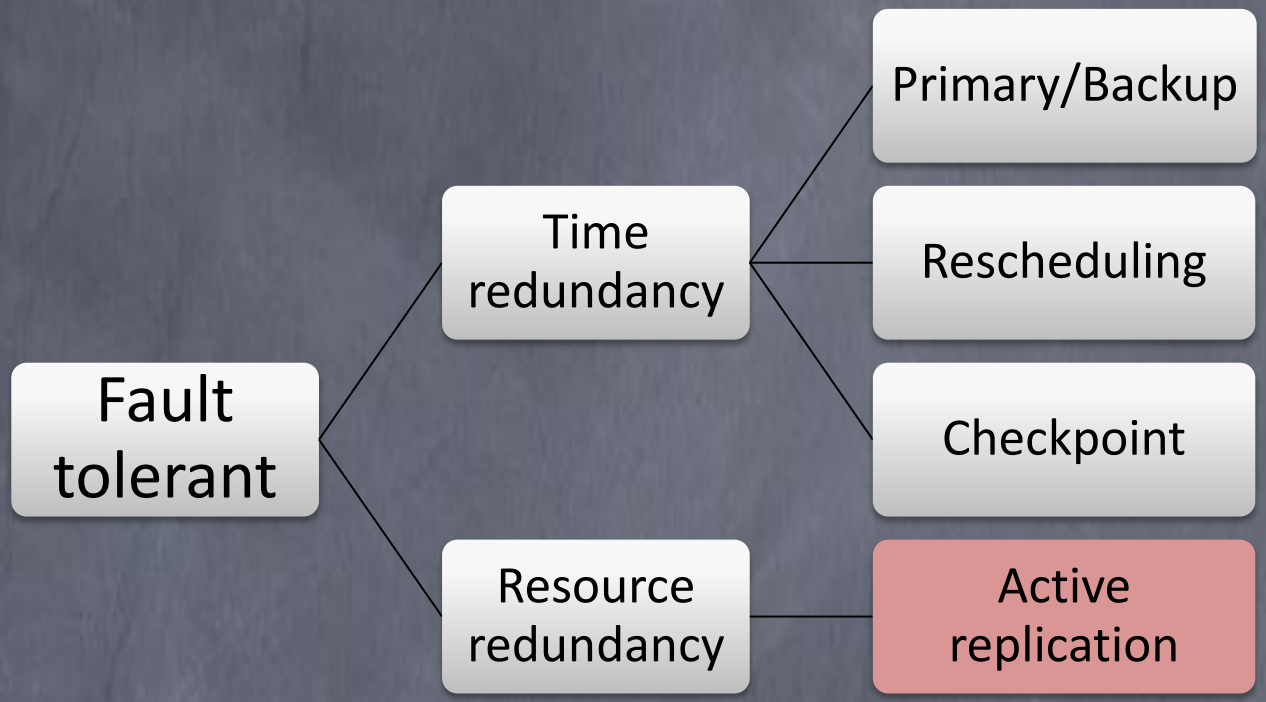
Fault tolerant technologies



- Two approaches for fault tolerance
  - Primary/Backup (Qin & Jiang, 2006; Zheng et al. 2009)
    - The backup is activated after the primary fails.
  - Active replication (Benoit et al. 2008, 2009; Zhao et al. 2010)
    - Simultaneously assign *f+1* replicas to different processors to tolerate *f* failures.

A comparison

	Primary/Backup	Active replication
Advantages	Less resource usage	Quick response
Disadvantages	Increase the execution time	Waste many resources
Target system	System with high system load	Hard time critical system with abundant resources

Energy consumption

Economic cost

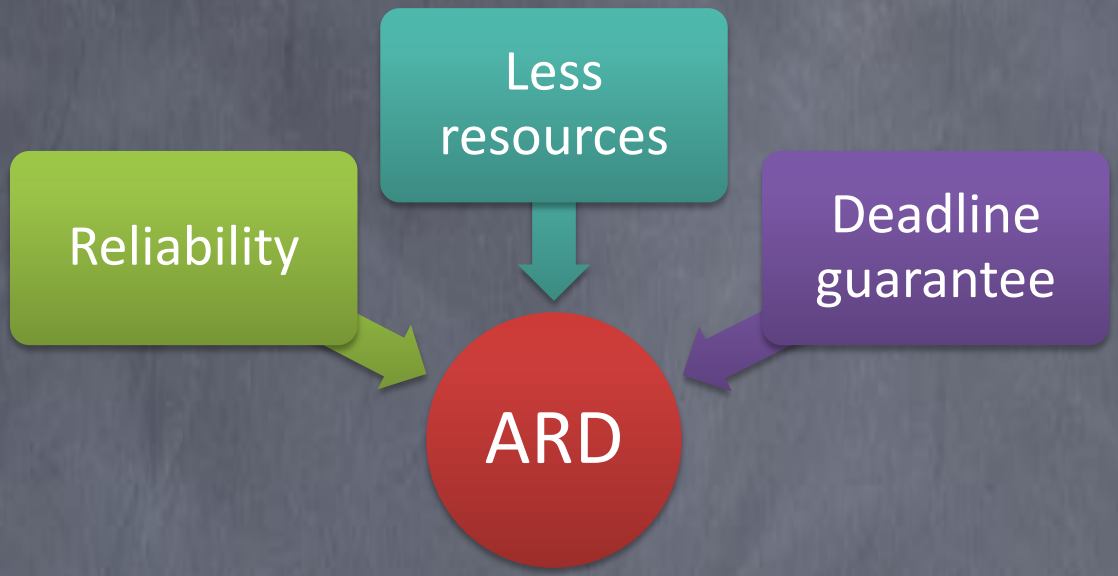
System throughput

etc…

Outline

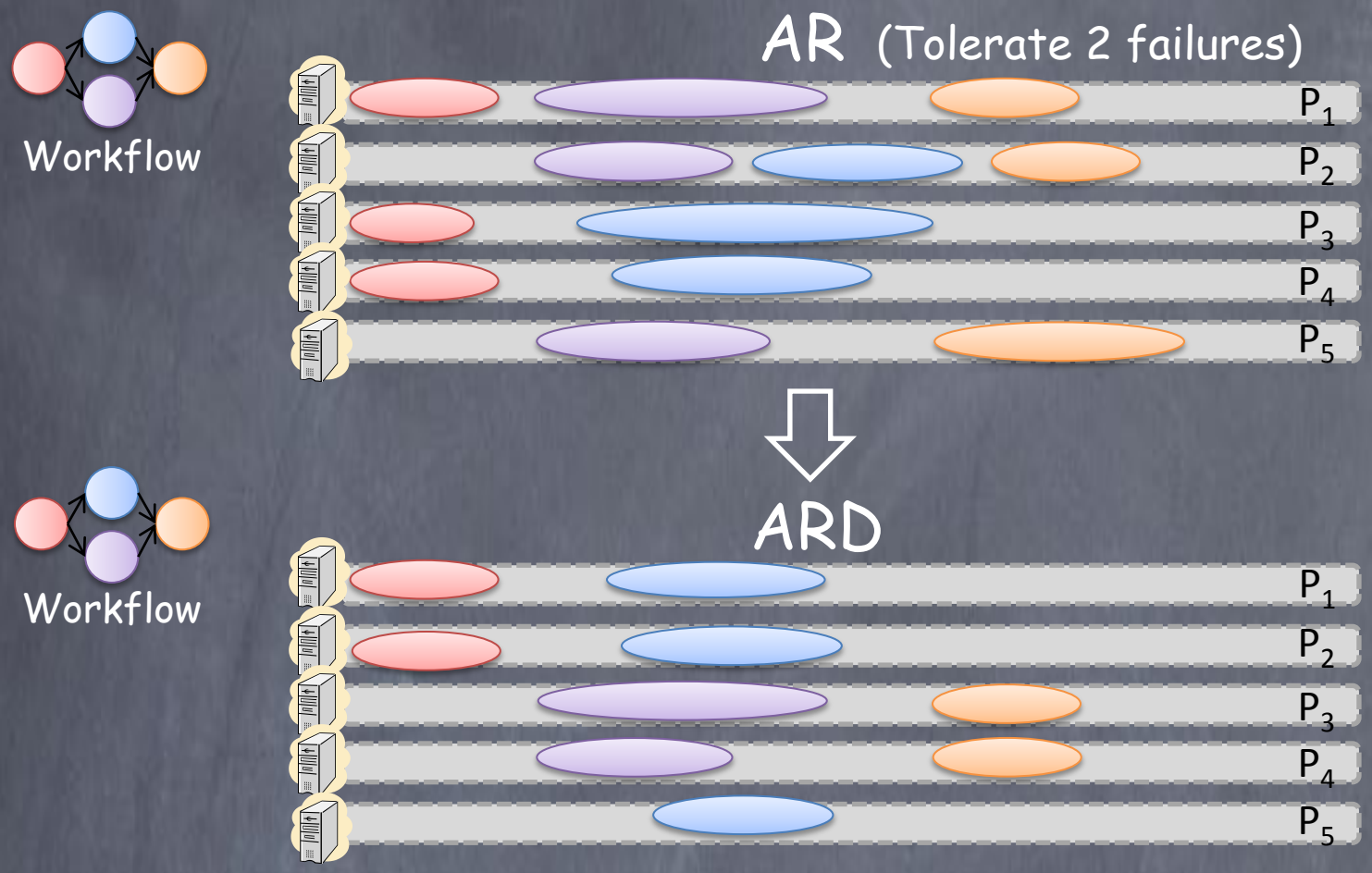
- Placing replicas to reliable processors
  - Reliability
  - Scheduling with meeting deadline
  - Task priority
- DRR scheduling
- Experiment
- Conclusion and future works

Active replication with dynamic number of replicas



- Active replication scheme with dynamic number of replicas (ARD):
  - Providing the same reliability as active replication (AR);
  - Using less replicas;
  - Ensuring the deadline.

Placing replicas to reliable processors



Placing replicas to reliable processors

- Providing the same reliability:

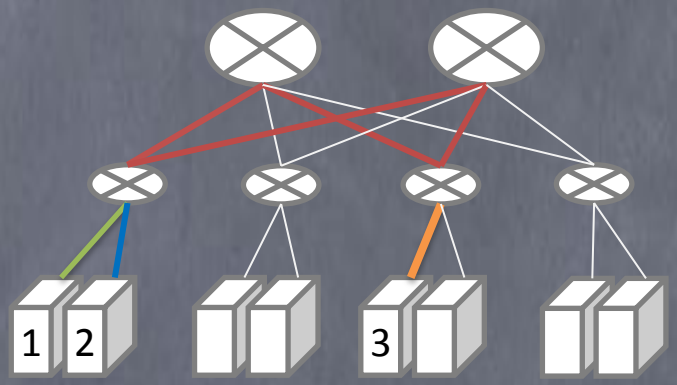
- How to provide a comparable reliability with less replicas?
  - Select processors with higher reliability.

Reliability

- Approaches for reliability analysis/prediction exist:
  - Javadi, Kondo, Vincent and Anderson (2009)
  - Narasimhan et al. (2005)
  - Oliner, Sahoo, Moreira, Gupta and Sivasubramaniam (2004)
  - Rood and Lewis (2010)
- For simplification,
  - Qin and Jiang (2006); Jin et al. (2009) etc.
  - Assume the failure distribution follows a Poisson process.

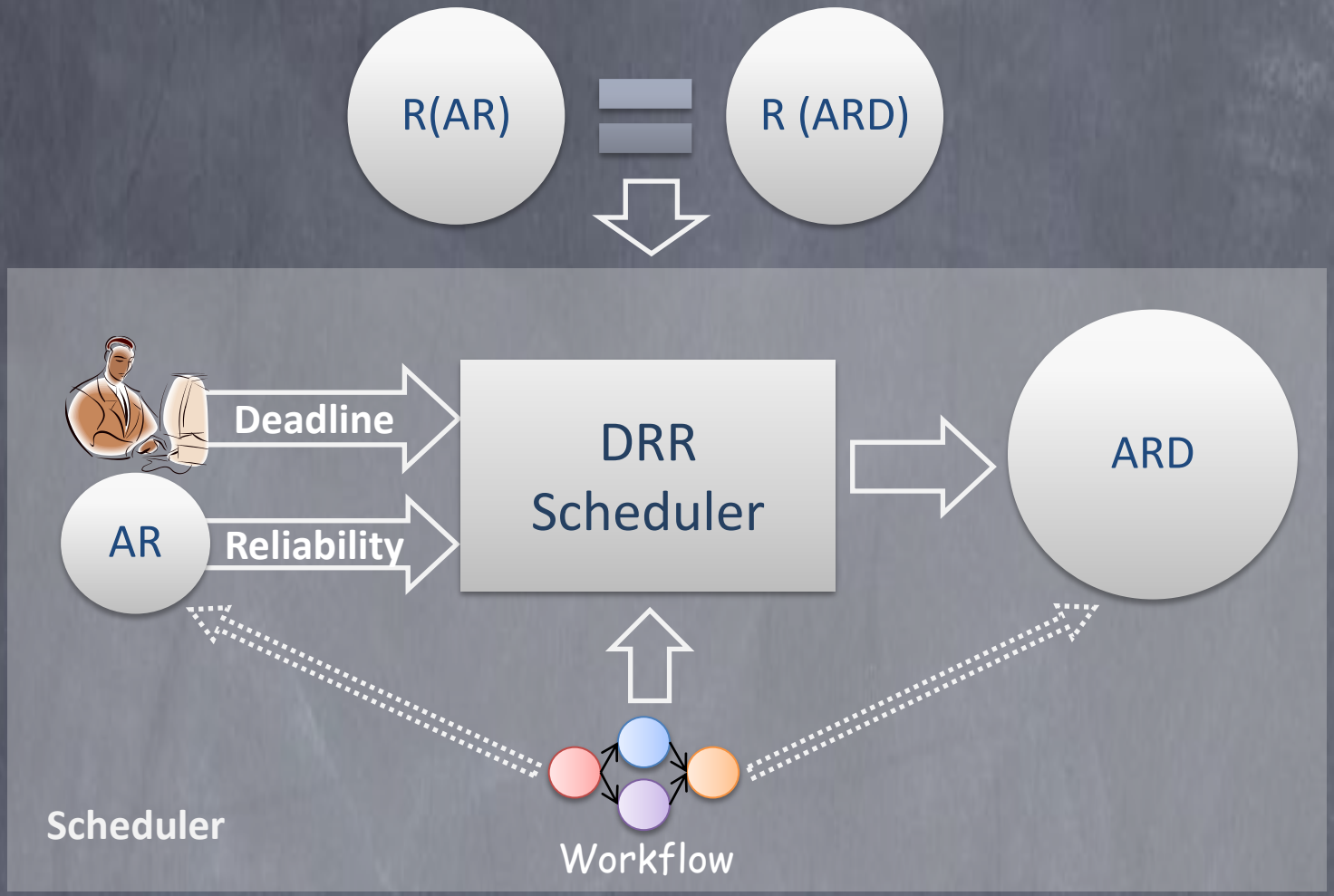
Reliability

- Reliability consists of computation and communication reliability.
- Computation reliability
  - $f(k,\lambda) = \dfrac{\lambda^k e^{-\lambda}}{k!}$



- Communication reliability
  - Processors in two tracks (e.g. 1 and 3)
    - Two possible communication paths
  - Processors in the same track (e.g. 1 and 2)
    - One communication path

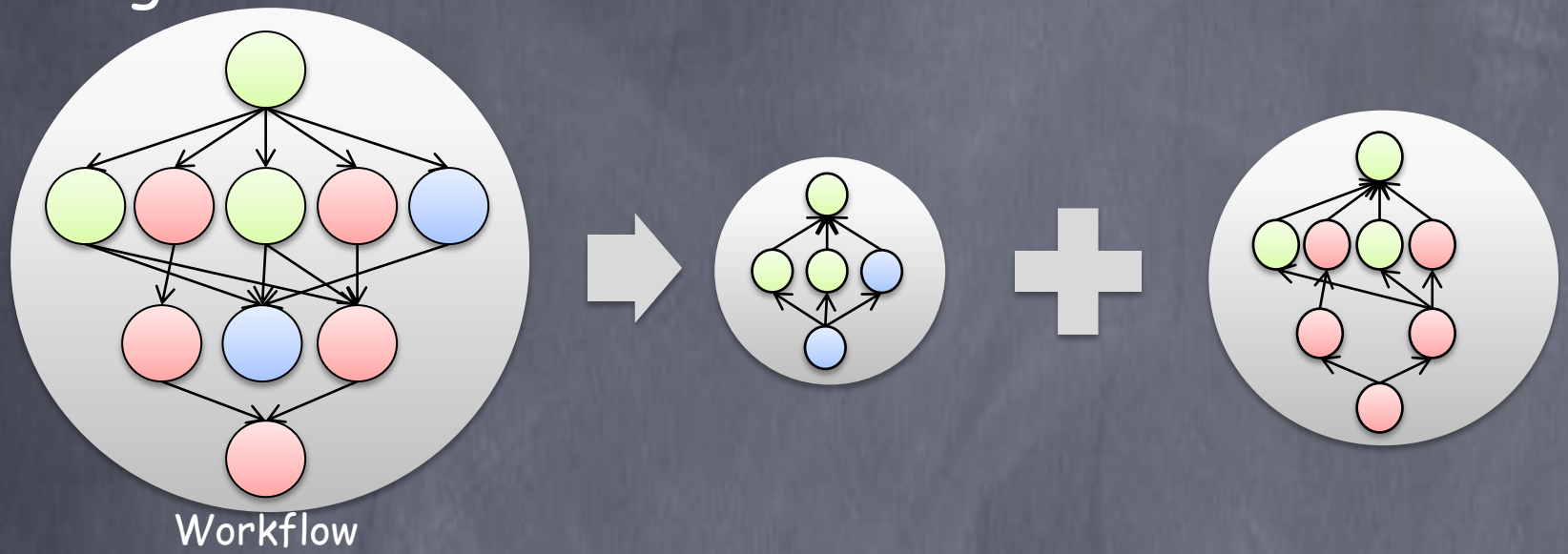
Scheduler



- The subreliability for a task should not less than: $r = \sqrt[n]{R}$, (n is the number of tasks in a workflow).

Scheduling with meeting deadline

- Breadth First Search (BFS) based subdeadline assignment:



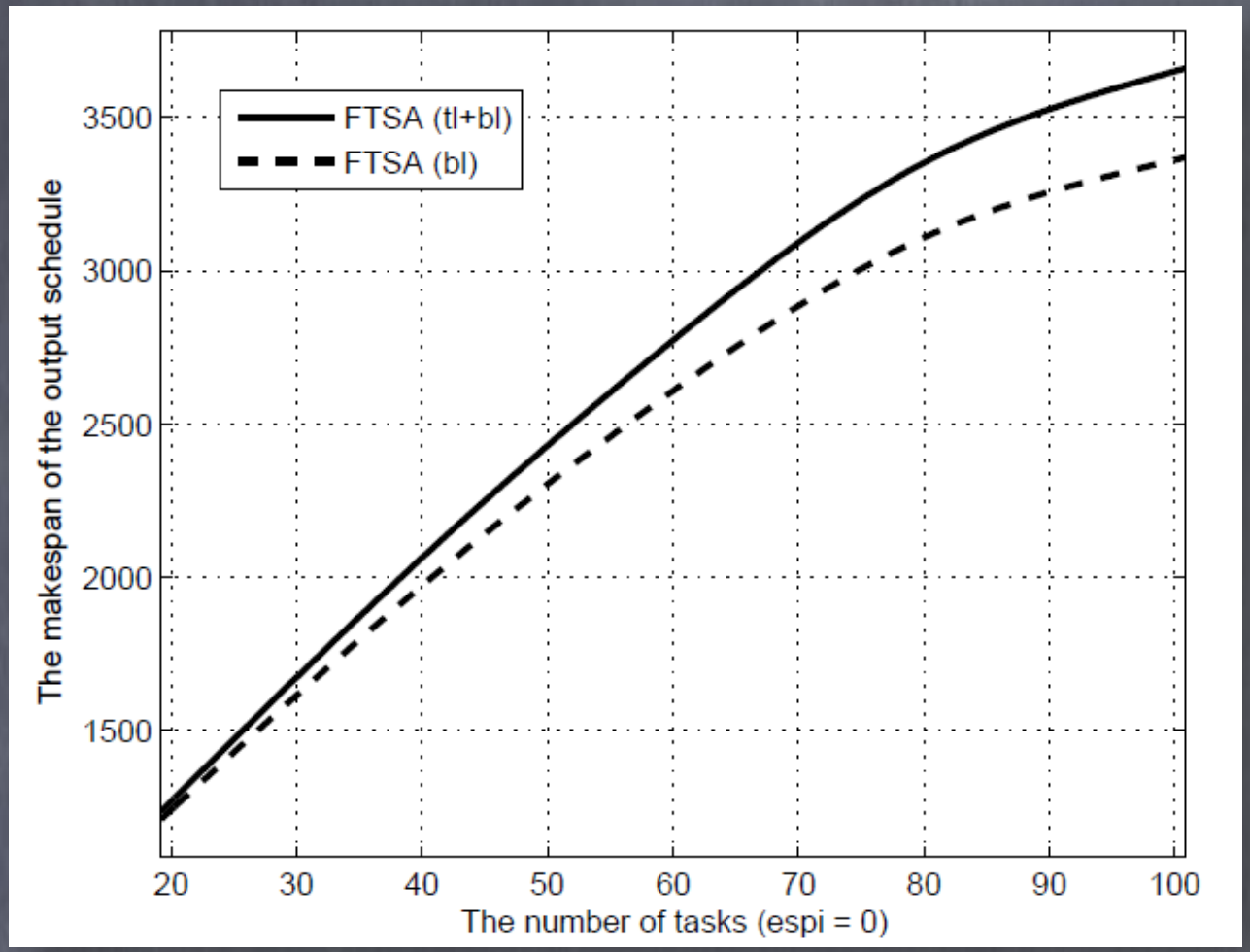
  - Subdeadline of the exit tasks equal to the overall deadline *T*.
  - Parents' subdeadline
    = Children's subdeadline – communication – execution;
  - Select the minimum value if multiple results are gotten.

Task priority

- Sorting tasks from a workflow into order, while ensuring the precedence relationship.

- Two approaches:
  - Bottom level (bl)
    - bl(x) = exe(x) + comm(x,y) + bl(y), y is a child of x.
    - HEFT (Topcuoglu et al. 2002); MaxRe(Zhao et al. 2010)
  - Top level + Bottom level (tl+bl)
    - tl(x) = tl(z) + exe(z) + comm(z,x), z is a parent of x.
    - FTSA(Benoit et al. 2008); CAFT(Benoit et al. 2009); CPOP(Topcuoglu et al. 2002).

Task priority



FTSA(bl) (Benoit et al. 2008) has a better performance than FTSA(tl+bl). Therefore, we use the tl value in our scheduling

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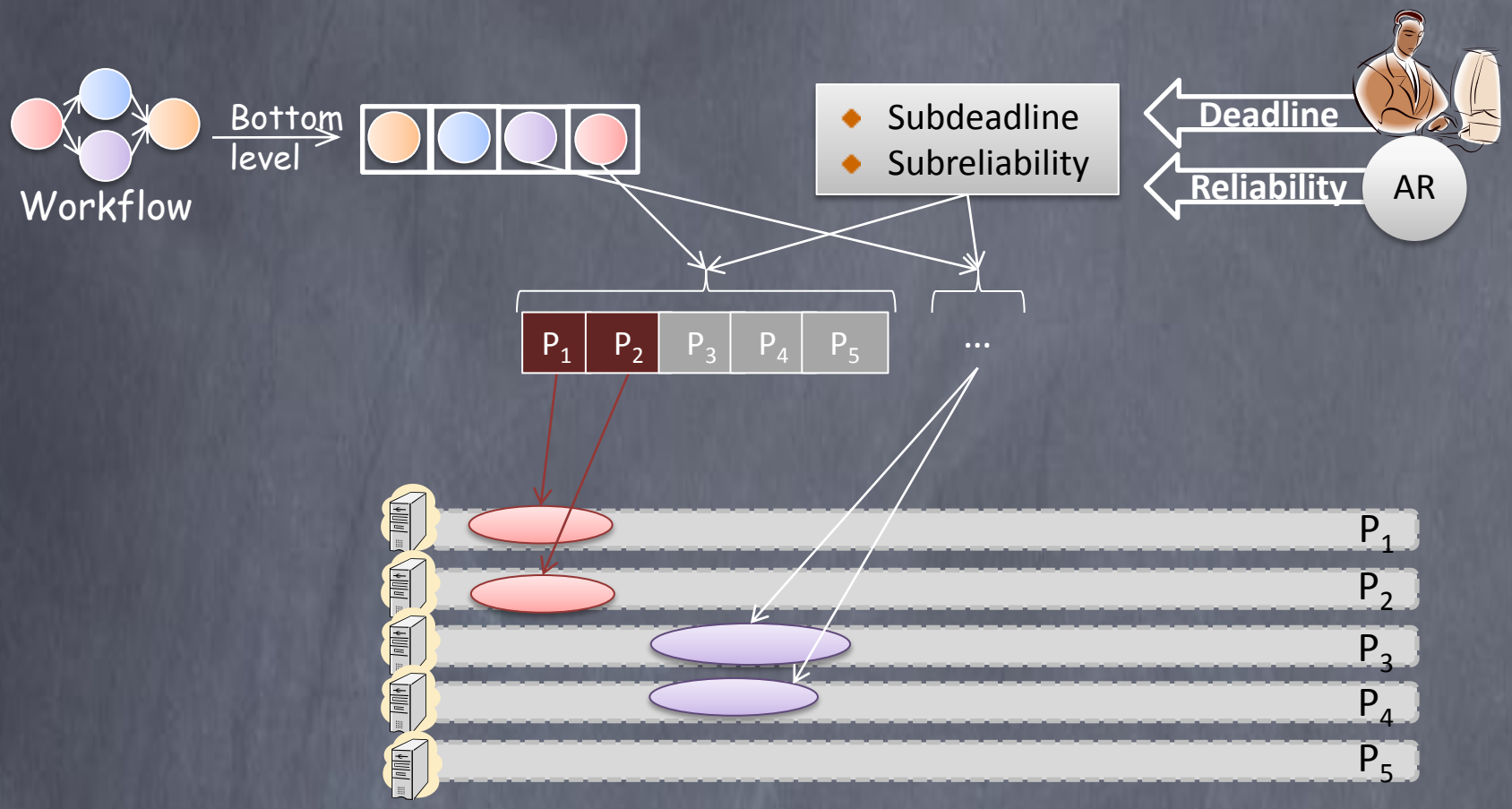
DRR scheduling

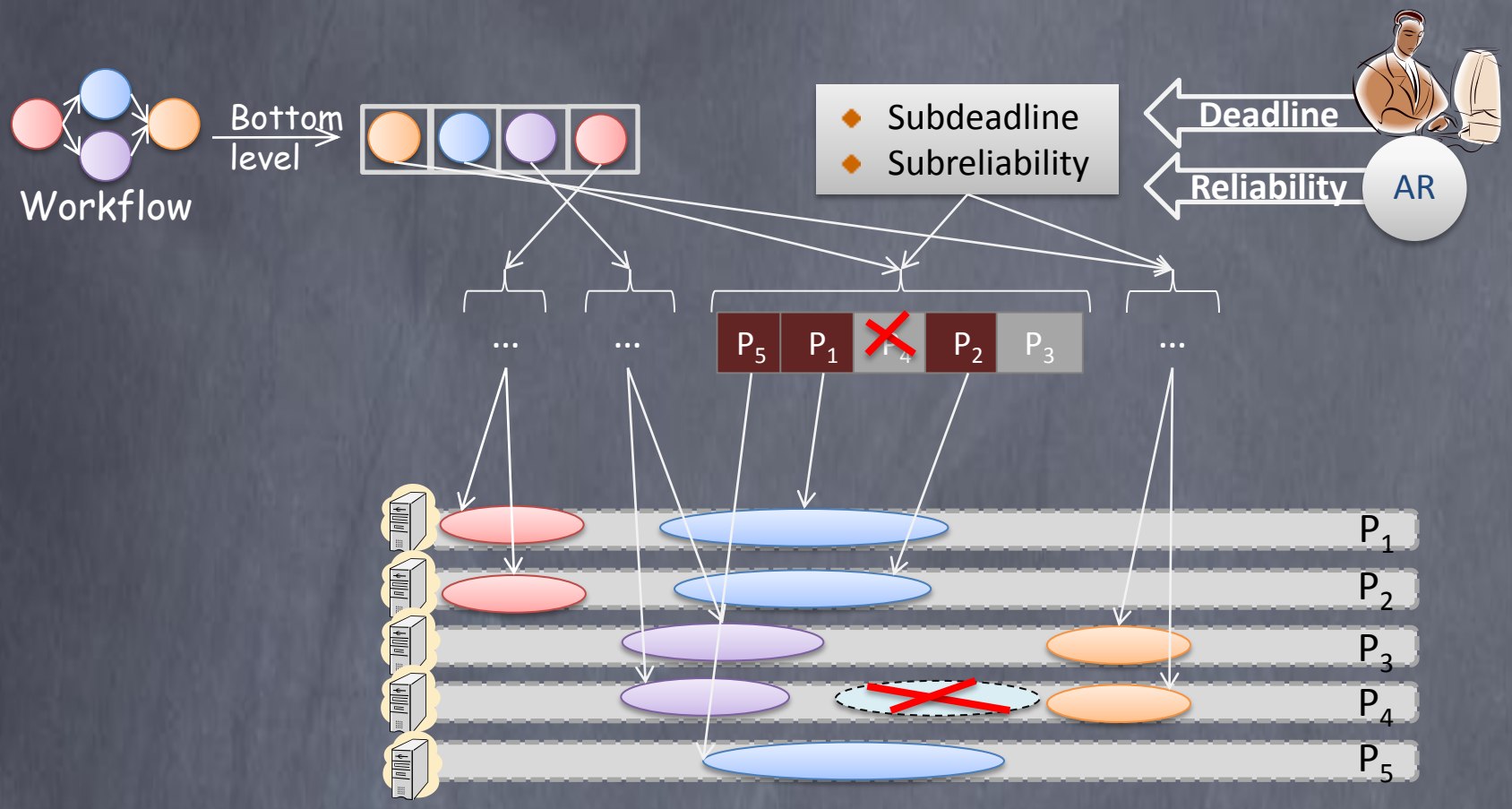
Deadline-Reliability-Resource-aware (DRR) scheduling:



DRR algorithm

DRR scheduling

Deadline-Reliability-Resource-aware (DRR) scheduling:

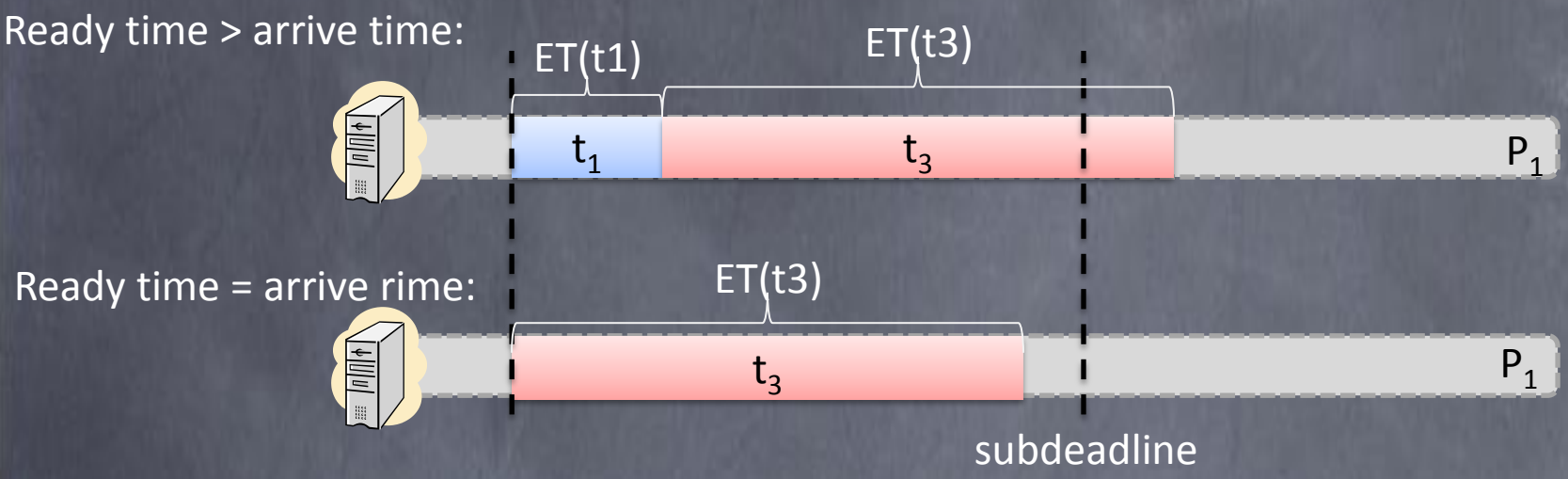


DRR algorithm

DRR optimization

- If a task subdeadline is violated by its finish time, the job will be rejected.
  - Proved by apagoge.
- For any entry task *x*, $ET(x) < subdeadline(x)$ cannot guarantee the job's successful completeness within deadline *T*.
  - Because of processor contention.

Processor contention



- Processor contention results in deadline violation.
  - In the case of ready time > arrive time,

    Subdeadline(t3) – ET(t3) < ET(t1),
  - The job will be rejected.

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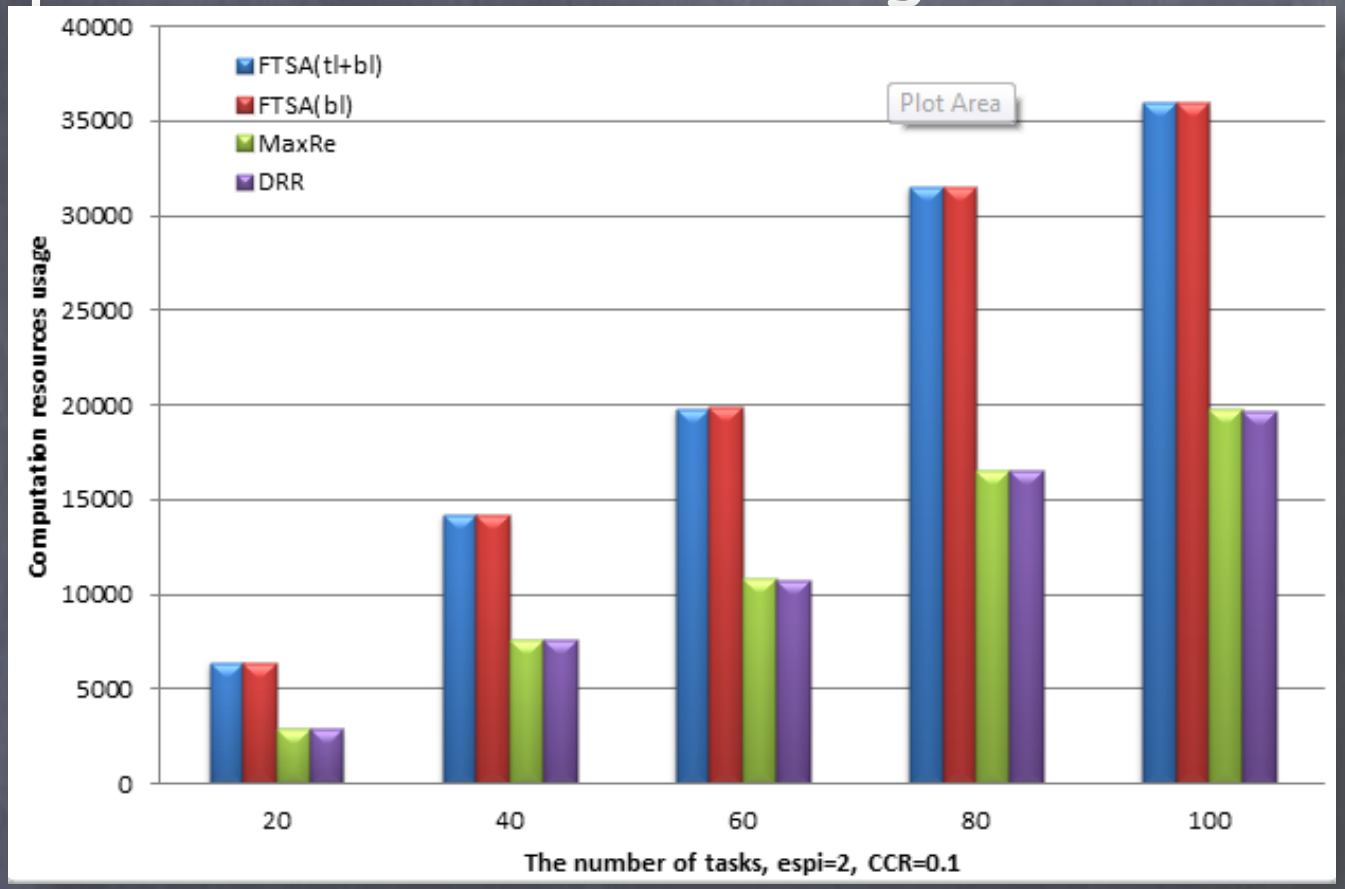
Experiments

- Simulation
  - Randomly generated graphs
  - Heterogeneous system
- Evaluation metrics:
  - Computation cost
    - Defined as the overall computation time of all processors.
  - Communication cost
    - Defined as the overall communication time of all communication links.

Experiments

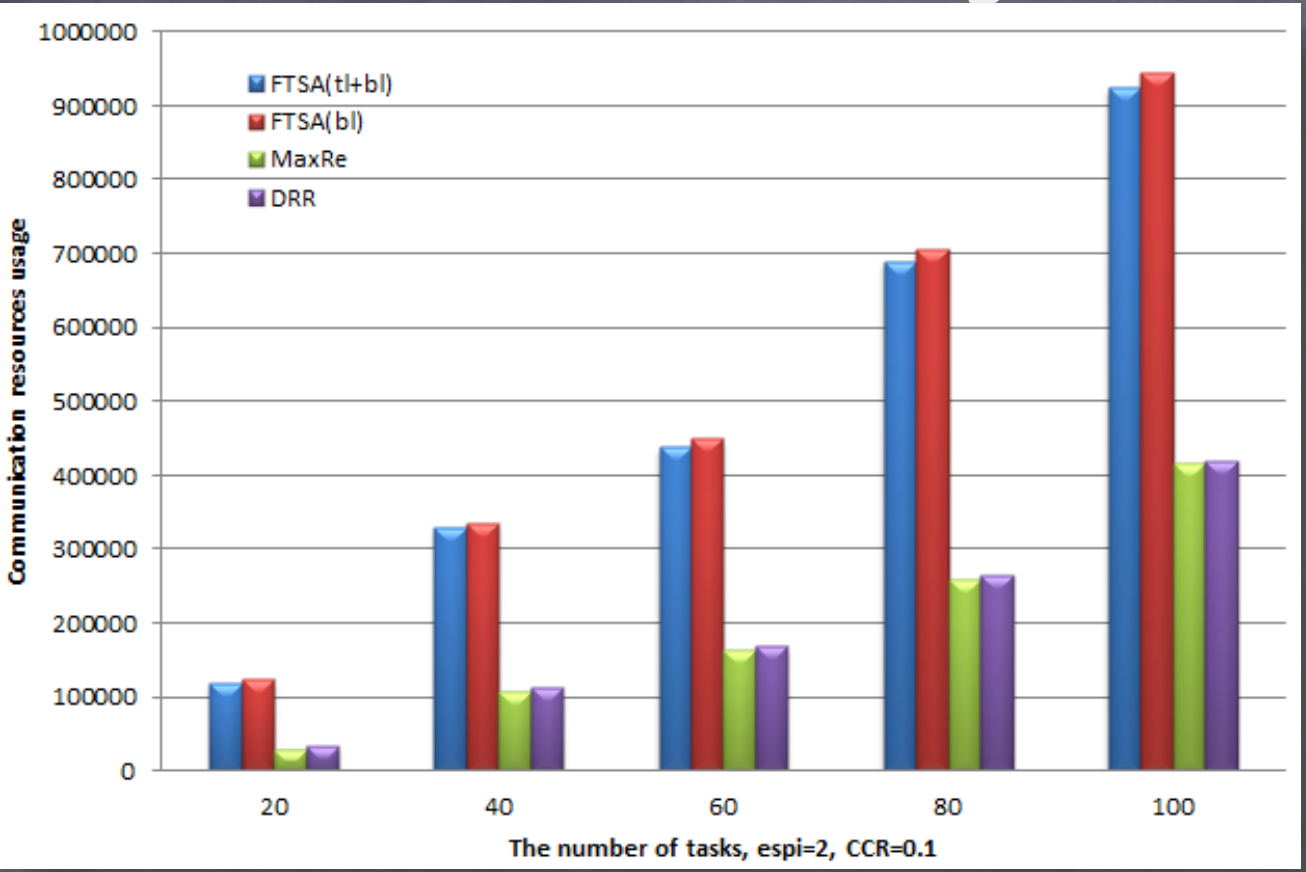
- Computation resource usage:



DRR and MaxRe save 50% computation resources.

Experiments

- Communication resource usage:



DRR and MaxRe save 70% communication resources.

Conclusion and future works

- This work improve the active replication scheme:
  - Achieves corresponding reliability with less resources;
  - Guarantee the deadline constraint.
- The future work:
  - A comprehensive study of both primary/backup and active replication based scheduling.

Thanks for the listening
Q&A