HAEP: Hospital Assignment for Emergency Patients in a Big City

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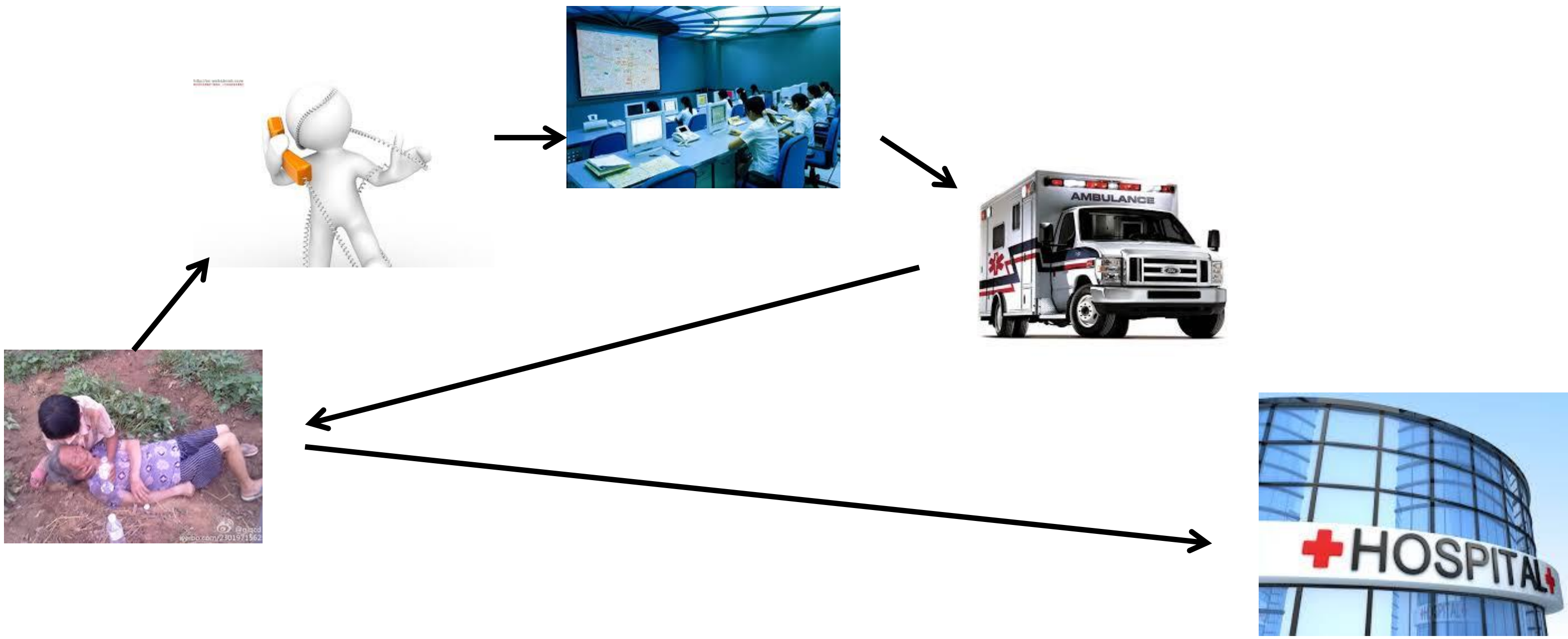
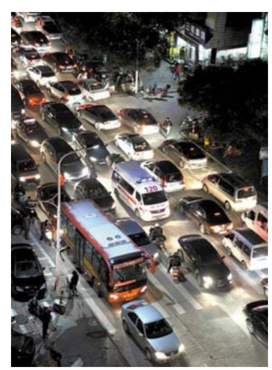
Hospital assignment in a big city

- Process of emergent patient caring





Major delay

But …
What it happens when arriving the hospital


Delayed in a hospital

- Death of the patient

- Poor doctor-patient relationship

Traditional greedy patient-hospital assignment

- First-come-first-serve (FCFS)
- Send the patient to a hospital with the shortest path

Sound good,   But

- A life-critical patient may not obtain the slot at that hospital when…

A non-critical patient comes from a closer place, or
A non-critical comes earlier

Problem

- In our system, there are three kinds of patients
  - Life-critical (e.g., massive haemorrhage, heart attack…)
  - Serious (e.g., detached limbs, food allergy…)
  - Cared (e.g., broken arm, stomach ache…)
- In our system, there are two kinds of hospitals
  - Premium hospital (treat all patients)
  - primitive hospital (treat non-critical patients)
- How to assign n patients to m hospitals with capacity C and across time scale
  - Minimize total delay

Existing solution (better use animation)

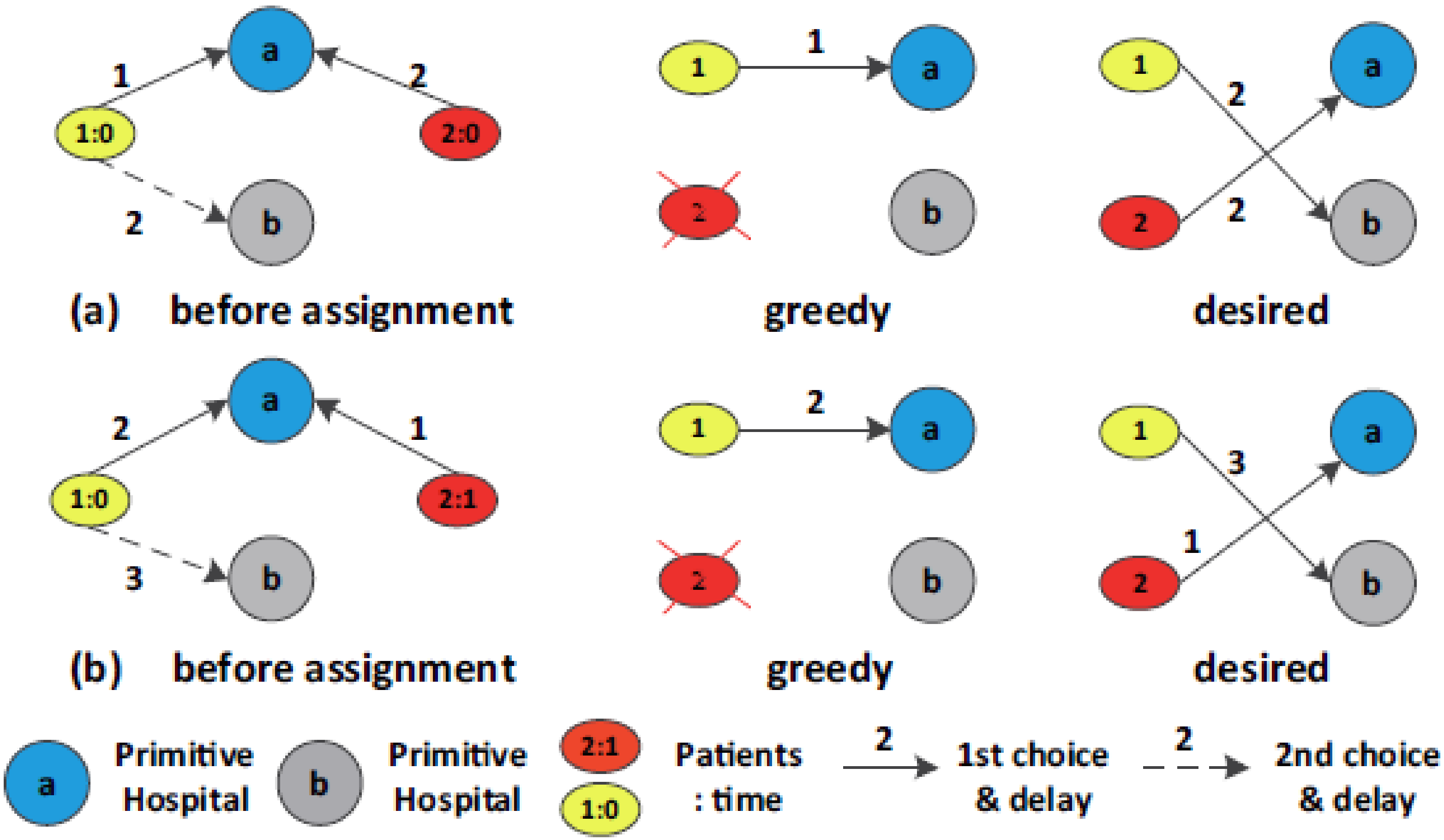


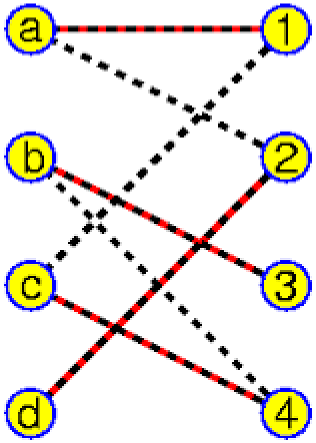
Fig. 1. A demonstration of patients and hospitals assignment

difficult to predict the assignment without accurate info.

Insight

When we have enough occupancy for demand

- Solution: Max-weight bipartite matching (Hungarian algorithm based K-M algorithm [J. Bondy'76])



- n patients, m hospital, extension
  - n is not equal to m
  - more than one node could be assigned to the same hospital

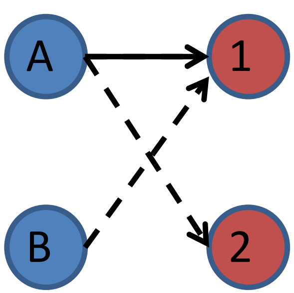
Key of the K-M algorithm

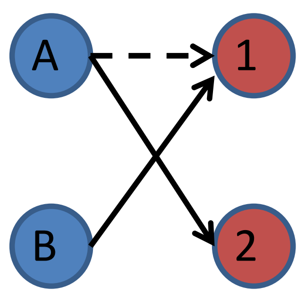
- Using labeling function *L* to find possible matching

$$L(x) + L(y) = R(x, y)$$

- Each step will find a local max-weight matching, if there's not enough resources, extend possible match by increasing and decreasing L by a small difference.

- If any better matching be found, could do assignment switching to correct results.





	1	2	
A	3	1	3 / 1
B	6	3	6
	0 / 2	0	

Our Solution

- Deal with multi-kind multiple requests and multi-kind
  - Partition hospital capacity into three parts

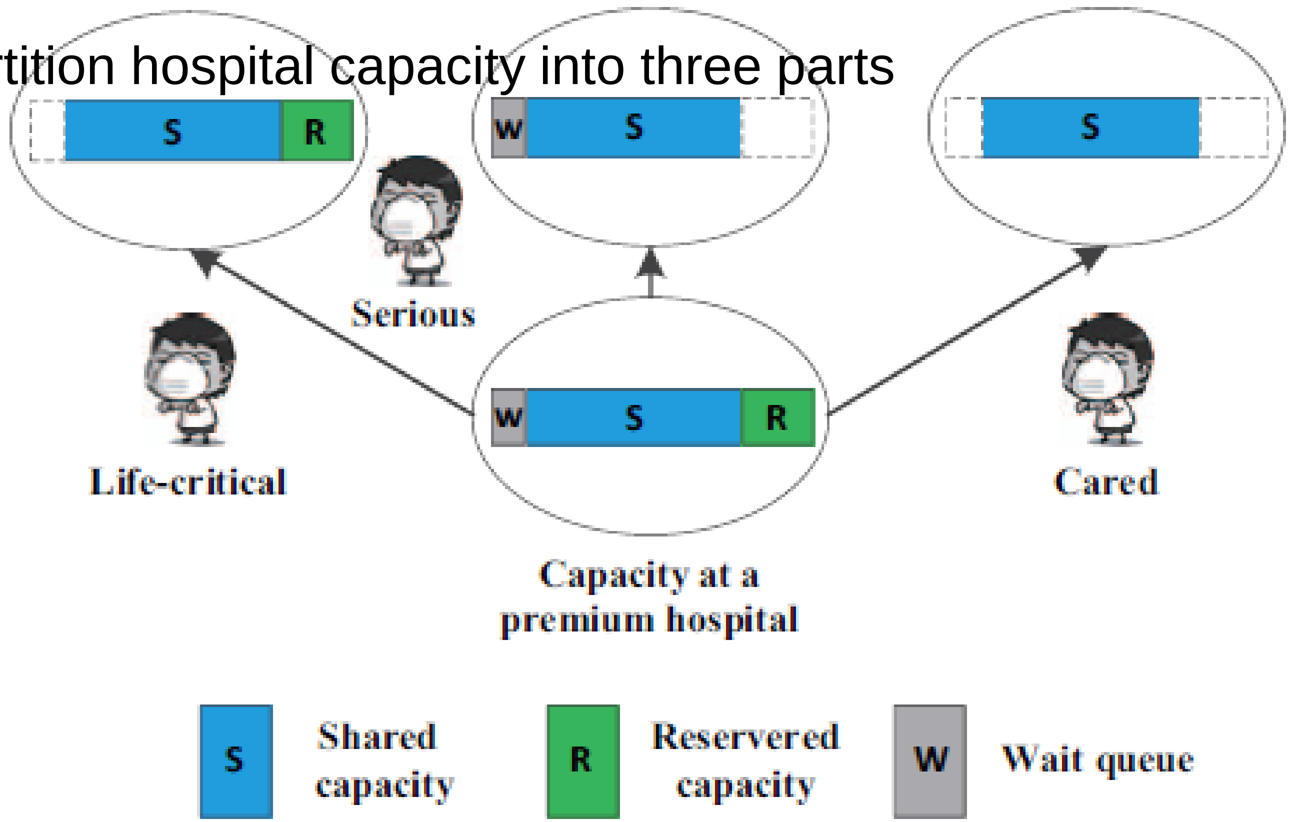


Fig. 2. Capacity illustration

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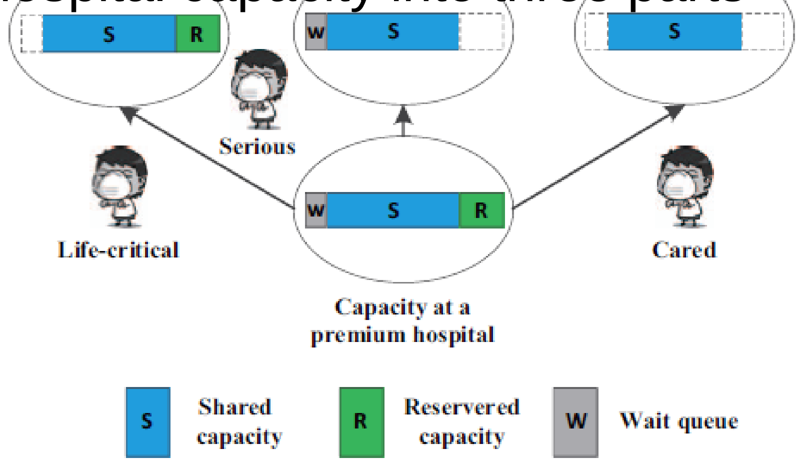


Fig. 2. Capacity illustration

- Optimization allocation across time period by
  - Preservation for life-critical patients ?
  - Waiting room for serious patients

Example

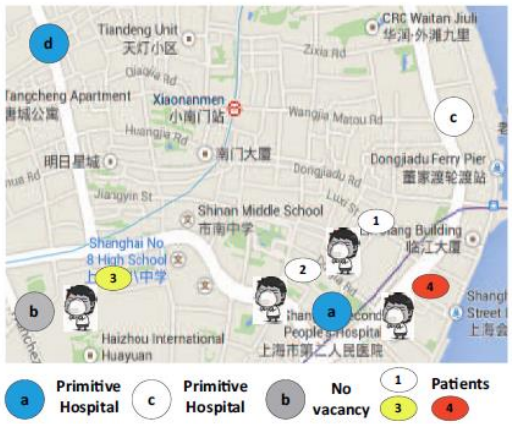


Fig. 3. A demonstration of patients and hospitals assignment

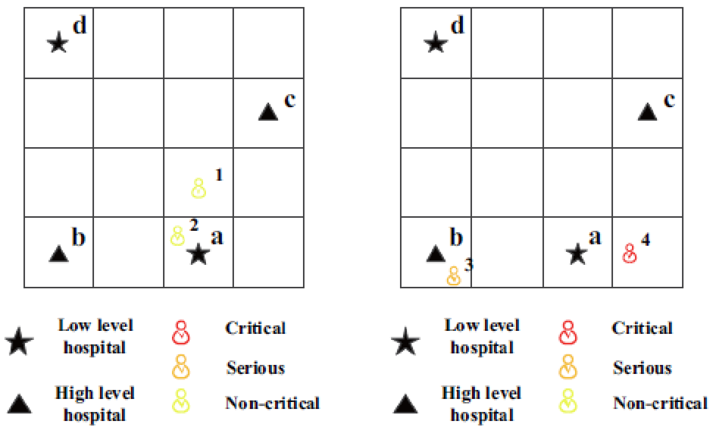


Fig. 4. Example illustration

$$CostMatrix(slot0) = \begin{array}{c} \\ 1 \\ 2 \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 1 & 3 & 2 & 4 \\ 0 & 2 & 3 & 5 \end{pmatrix} \end{array} \qquad (1)$$

$$CostMatrix(slot1) = \begin{array}{c} \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{pmatrix} 2 & 0 & 5 & 3 \\ 1 & - & - & 6 \end{pmatrix} \end{array} \qquad (2)$$

Example

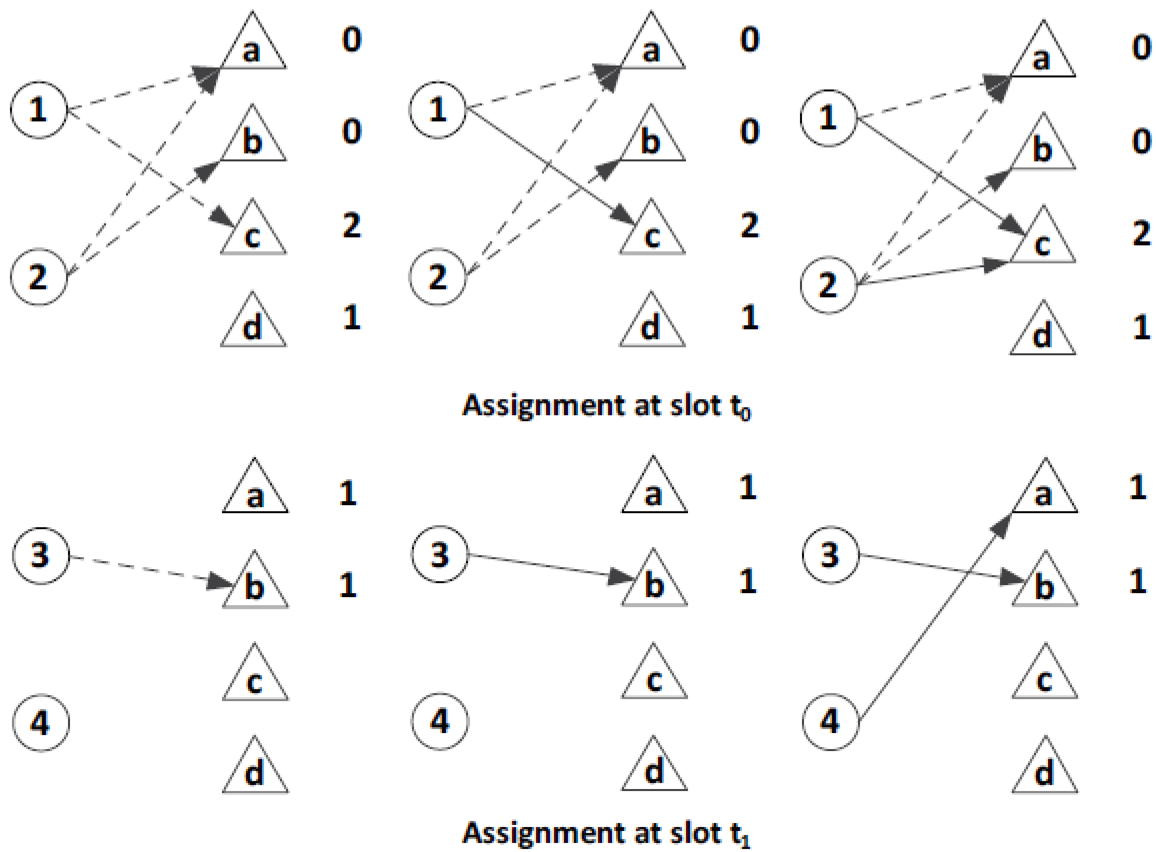


Fig. 5. Our matching at slot t_0 and t_1

Calculation of parameters

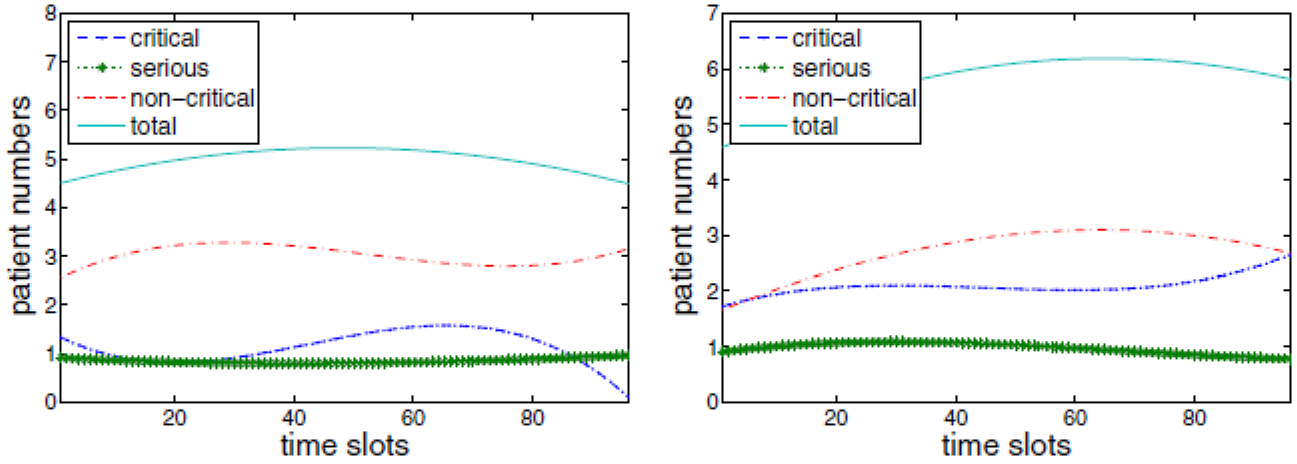
-

- Size of preservation
  - last three data sets as history to estimate the future
  - α and β are constant coefficient where α + β = 1
  - γ is is a compensatory factor

$$R_{i+1} = r_i + \frac{\alpha \times (r_i - r_{i-1}) + \beta \times (r_{i-1} - r_{i-2})}{2} + \gamma$$

Simulations

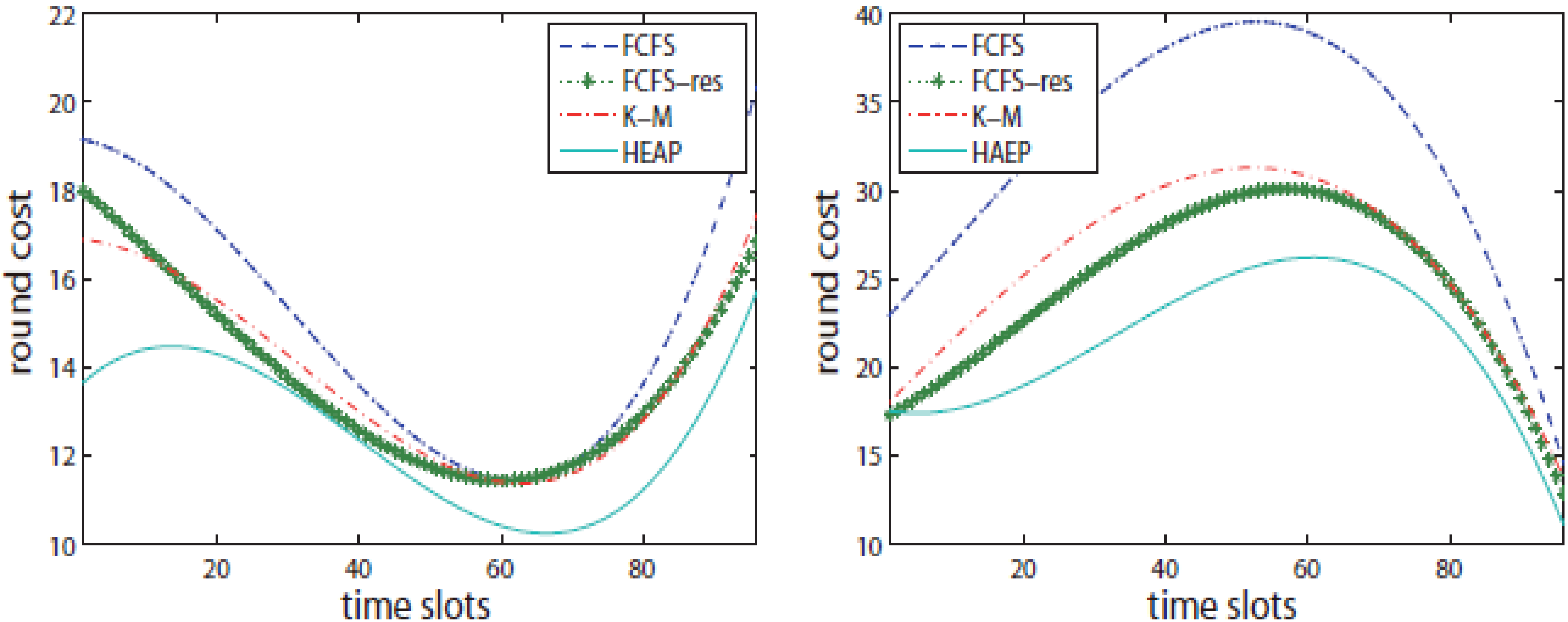
- Patient number varies along time



(a) patient number of regular days (b) patient number of peak days

  - 4x4 grid with distance 5 min, Poisson dist. to generate patients
  - 4 hospitals in total (two premium, 2 primitive), each 120 beds
- Competitors
  - Nearest-first(FCFS) and with reservation (FCFS-res)
  - K-M algorithm extended with capacity(K-M)

Total delay

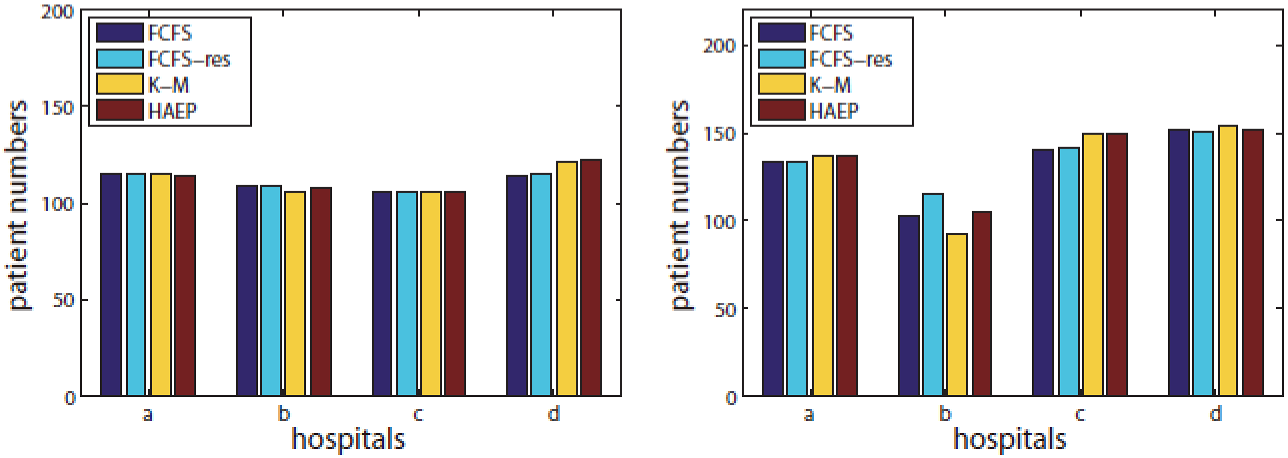


(a) round cost of regular days

(b) round cost of peak days

- K-M and FCFS-res will give more benefit to serious and critical patients so that some noncritical patients will be affected

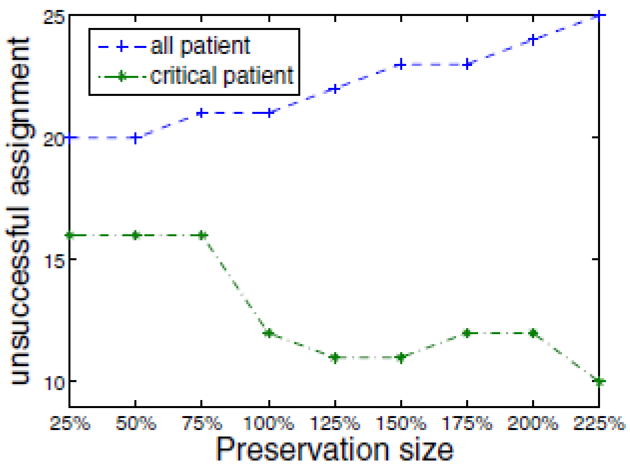
Distribution of patients



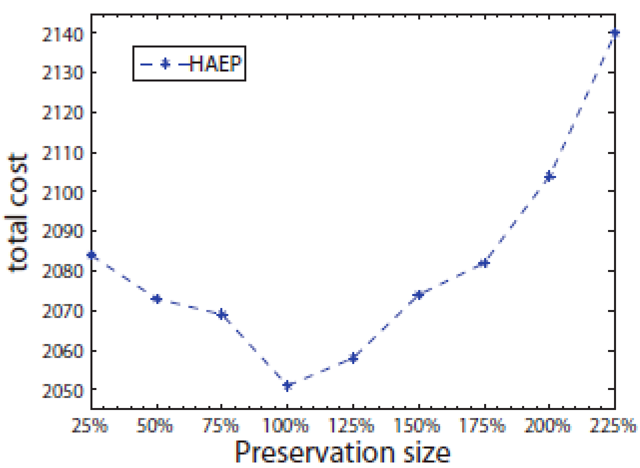
(a) distribution of regular days (b) distribution of peak days

- FCFS − res and HAEP consider the requirements from critical patients so that premium hospital a and d gets more patients in.
- HAEP uses the reservation so that some noncritical patients will go further, and primitive hospital will get more patients.

Extension work with different preservation size



(a) distribution of regular days



(b) distribution of peak days

- The experiment is based on one extremely completive test instance of 96 rounds.
- It is obviously a tradeoff between total cost and benefit of critical patients to find best point of preservation size.

Conclusion

- we propose a novel emergent patient assignment to minimize the average delay of patients, as well as the amount of failure-of-assignment for critical patients in the large city, denoted by HAEP.

- The solution is built on the Hungarian algorithm, with the prediction and time scale, applied on a multi-imension resource and requesters.

Thank you!