Computational Integer Programming
Exercise 05: Vehicle Routing

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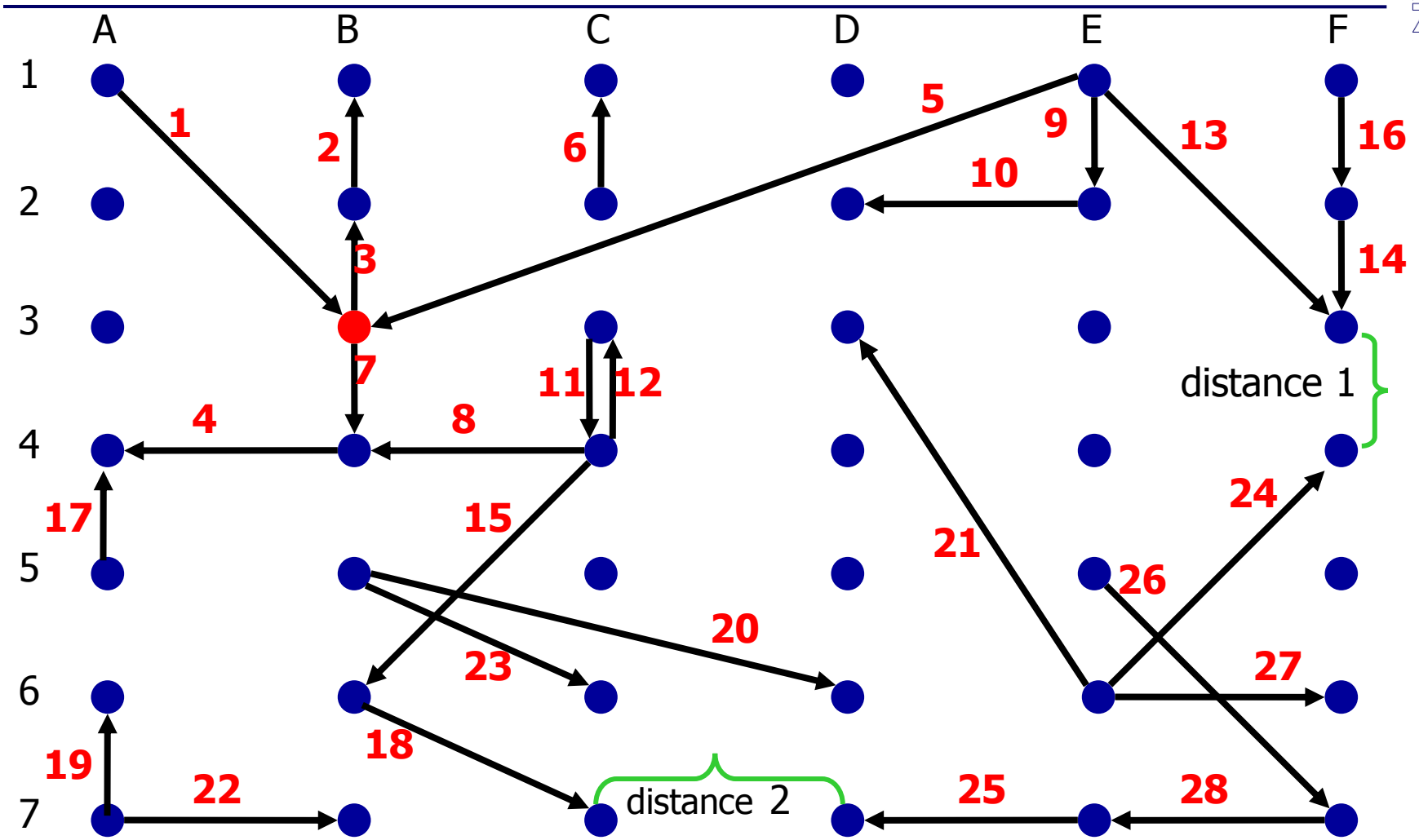
Description of Transportation Services Needed

- You get a map from which the requested transportation services (called contracts) can be inferred. For each contract, a load has to be picked up at a starting point and has to be delivered to a terminal point.
- Each arrow indicates a contract and has a red id number.
- There are only "horizontal" and "vertical" streets. Horizontal street segments have length 2, vertical ones have length 1.
- All trucks have to be rented from a central truck service company.
- There is one common starting point for all trips of all trucks.
- TU has its own fleet of very costly small trucks. These will take care of the contracts not assigned to bidders.

The Contracts



- The distance between two nodes is the sum of the horizontal and vertical distances (Manhattan distance), e.g., the distance between A6 and C5 is 5.
- The red numbers are the id numbers of the contracts. The arrows show the directions.
- The red point B3 is the starting point for all trucks.

Vehicle Routing Model Skeleton

```
param FIX := 10; # cost for a vehicle
param LEN := 30; # max route length

# nodes, depot (first node), trips, arcs
set V := { read DAT as "<1n>" comment "#" };
param depot := ord(V,1,1);
set W := V \ { depot };

# trip coordinates from {1..7} * {A..F} * {1..7} * {A..F}
param y1[V] := read "trips.dat" as "<1n> 2n" comment "#";
param x1[V] := read "trips.dat" as "<1n> 3s" comment "#";
param y2[V] := read "trips.dat" as "<1n> 4n" comment "#";
param x2[V] := read "trips.dat" as "<1n> 5s" comment "#";

# character coordinates
set CHAR := { "A", "B", "C", "D", "E", "F" };
param ind[CHAR] := <"A"> 1, <"B"> 2, <"C"> 3, <"D"> 4, <"E"> 5, <"F"> 6;

# distance from the start of trip u to the end of trip u to the start of trip v
defnumb dist(u,v) := 2 * abs(ind[x2[u]]-ind[x1[u]]) + abs(y2[u]-y1[u])
                   + 2 * abs(ind[x2[u]]-ind[x1[v]]) + abs(y2[u]-y1[v]);
```

The Expense

- Trucks must be rented. Each truck costs 10 Euros. This fixed cost is independent from the distance travelled.
- Each truck is, however, allowed to travel only at most 30 distance-units.
- Variable costs: Each running-distance-unit costs 1 Euro.
- The expense is the sum of the rental fee (fixed cost) and the operating cost (variable cost) of each truck.
- Each truck may serve several contracts consecutively, but can carry the load of only one contract at any point in time.
- Each truck has to start and end at B3.

The Auction

- The TU needs (cheap) transportation service.
- The participants of this course are eager to provide it.
- The audience in this room will have to form several bidder-teams, i.e., you have to get organized.
- Each bidder-team consists of (at most) 6 persons.
- Each team represents a haulage company (carrier), which wants to bid for transportation contracts and thereby obtains its profit (earnings minus expenses):
  - In your bids you have to offer how much you want to charge for executing the contracts (your earnings). The currency is Euro and the bidding-unit is 1 cent, i.e., it is allowed to charge e.g. 10.01 €.
  - The expenses are due when you execute the contracts.

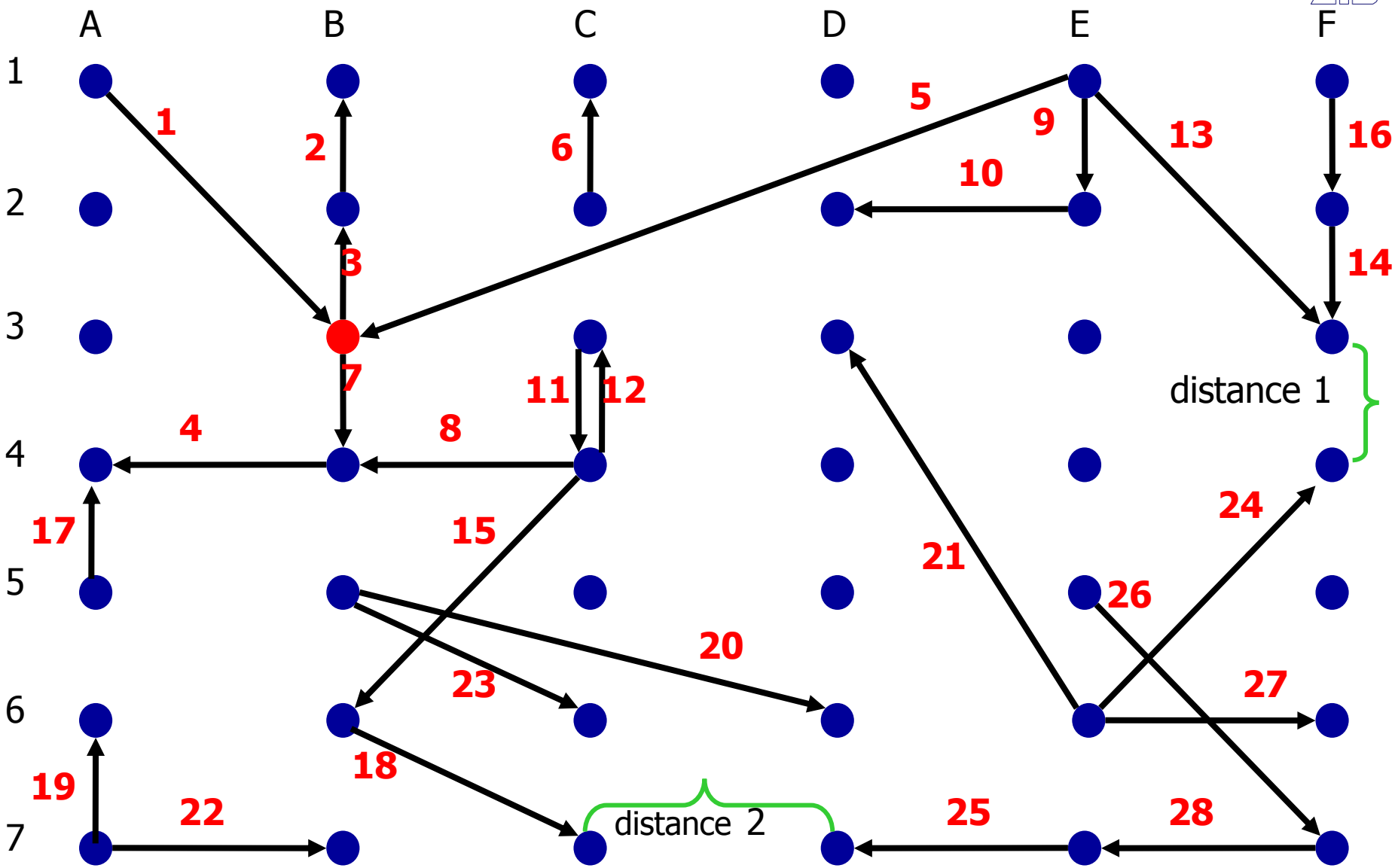
The Auction Rules

- There are several auctioning rounds, at least 3.
- In each round, each team can give one bid. Each bid consists of at most 6 contracts, e.g., team 1 may offer to fulfill contracts 1, 4, 8, and 11 for 25 Euros (this is the amount TU will have to pay to team 1 if it wins the bid).
- Once all bids are submitted, the principal (TU) will determine the least cost combination of all bids serving all its requests (the allocation) and disclose which bids win at the current round. However, he will only tell which team receives which contract and the total price TU will pay for all contracts (but not the price for any single winning bid), e.g.,
  - Team 1 gets contracts 1, 4, 8, and 11; team 2 gets contract 5, etc.
  - The total price is 150 Euros.
- The next round starts afterwards. Again each team can give a bid. BUT the bids of the previous rounds remain. In other words, after 3 rounds each team may have 3 different bids in the auction.
- The auction stops when the principal is satisfied with the outcome, or when there are no further bids.

The End

- When the auction stops, the allocation of the last round is final. Each team obtains the prices of ist winning bids as the earnings.
- Each team has to calculate ist expenses to execute its winning bids.
- The team with the largest profit is the winner.
- The bidding process is run electronically on the principal´s laptop.

Map


A
B
C
D
E
F
1
2
3
4
5
6
7
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
distance 1
distance 2

Bids

Team	Round	Bid/€	Contracts

Bids

Team	Round	Bid/€	Contracts

Allocation

Round	Total/€	Contracts

Allocation

Round	Total/€	Contracts

Profit

Team	Bid/€	Cost/€	Contracts
Profit			