Efficiency of navigation in indexed networks

Petter Holme

Royal Institute of Technology (Sweden), University of New Mexico (USA)

October 5, 2007, ECCS satellite workshop

http://www.csc.kth.se/~pholme/

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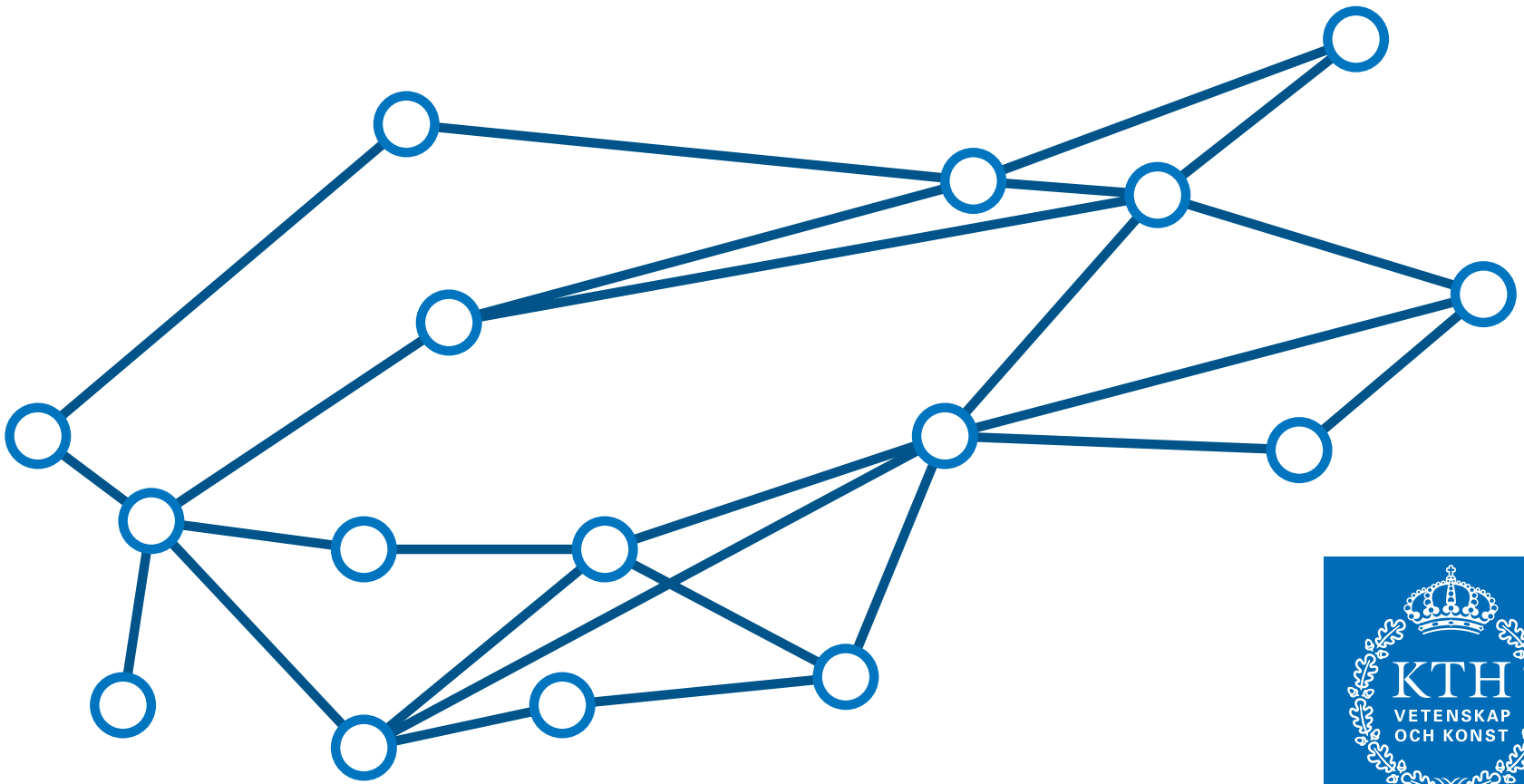
a graph



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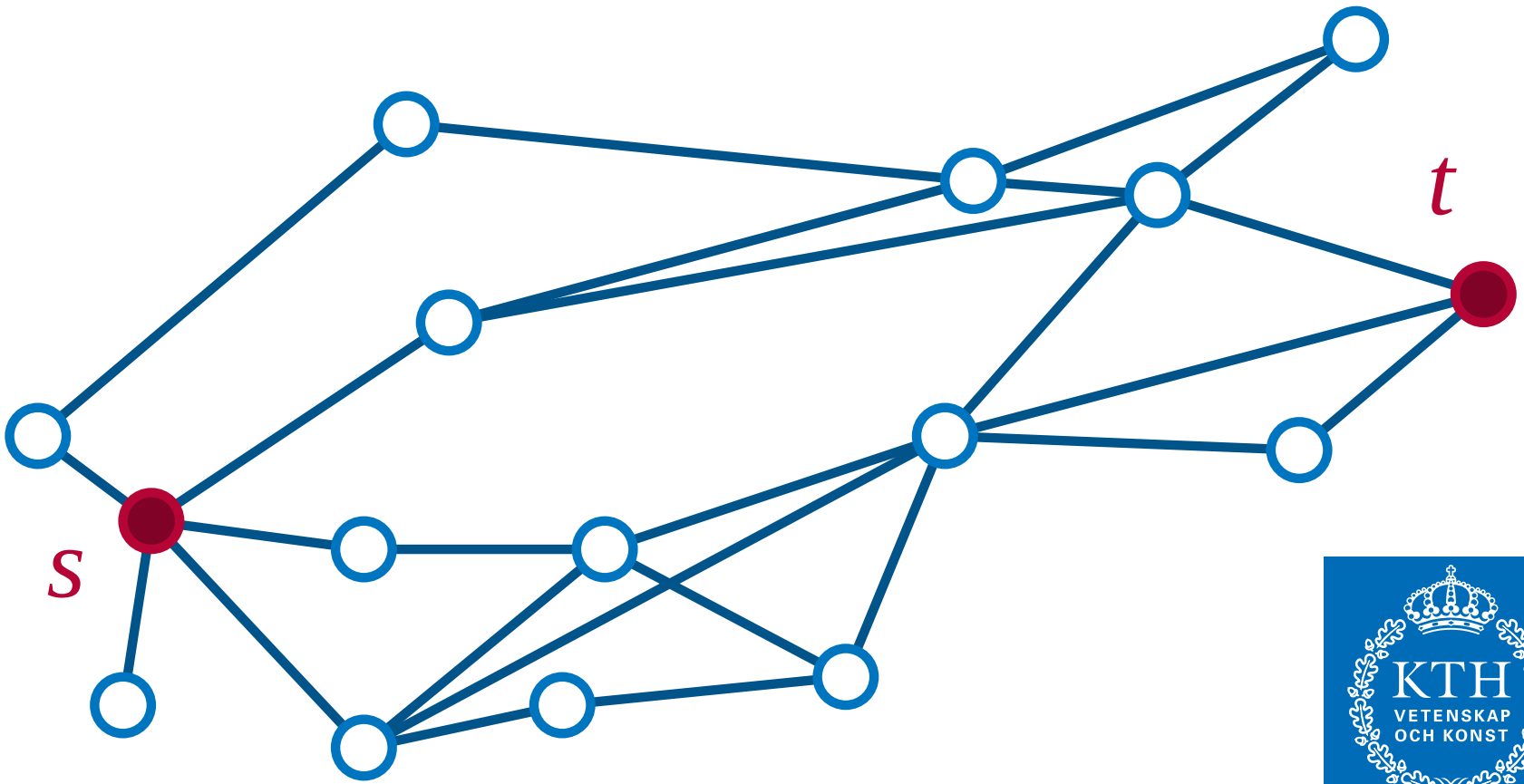
source & target



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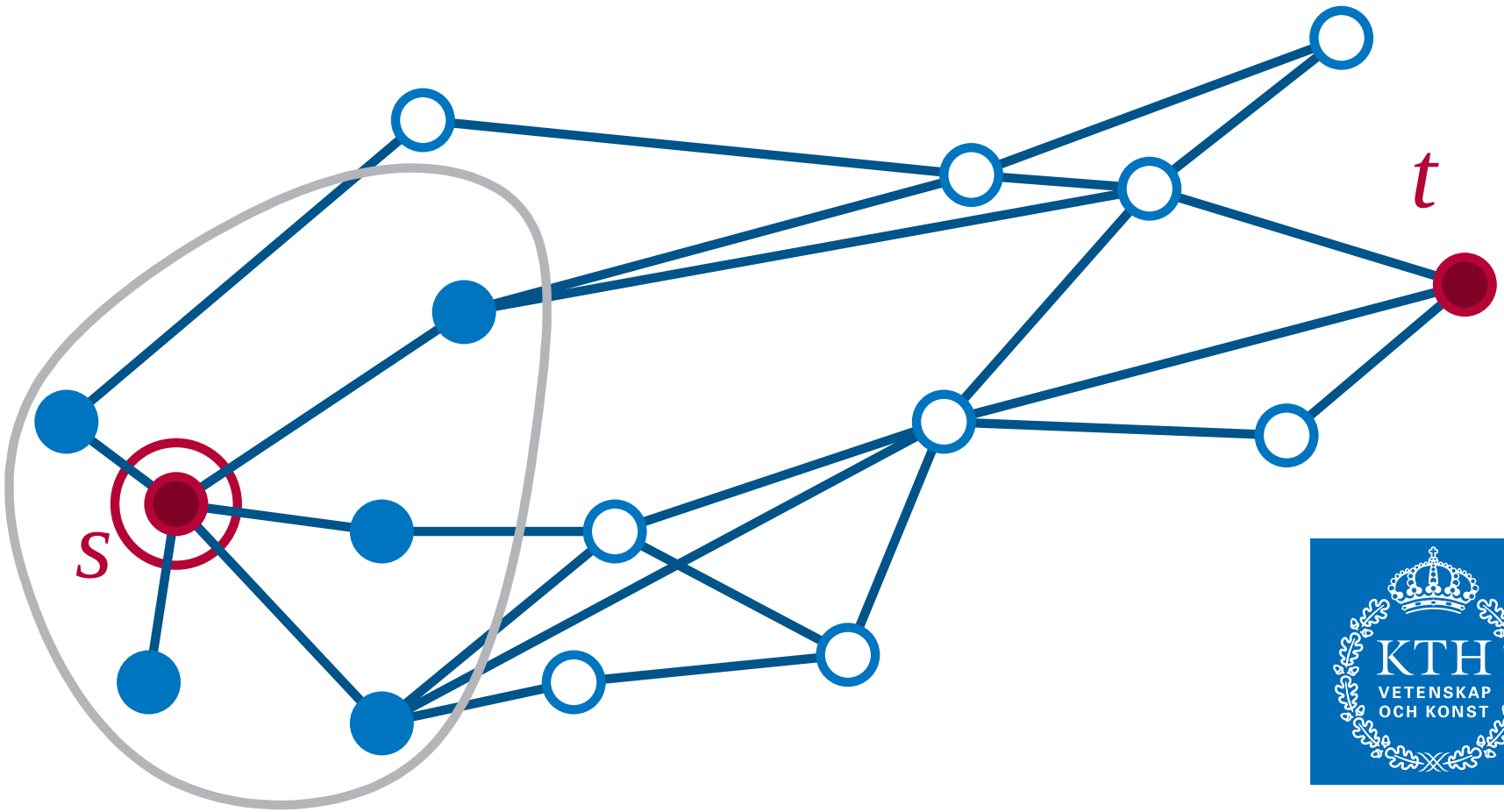
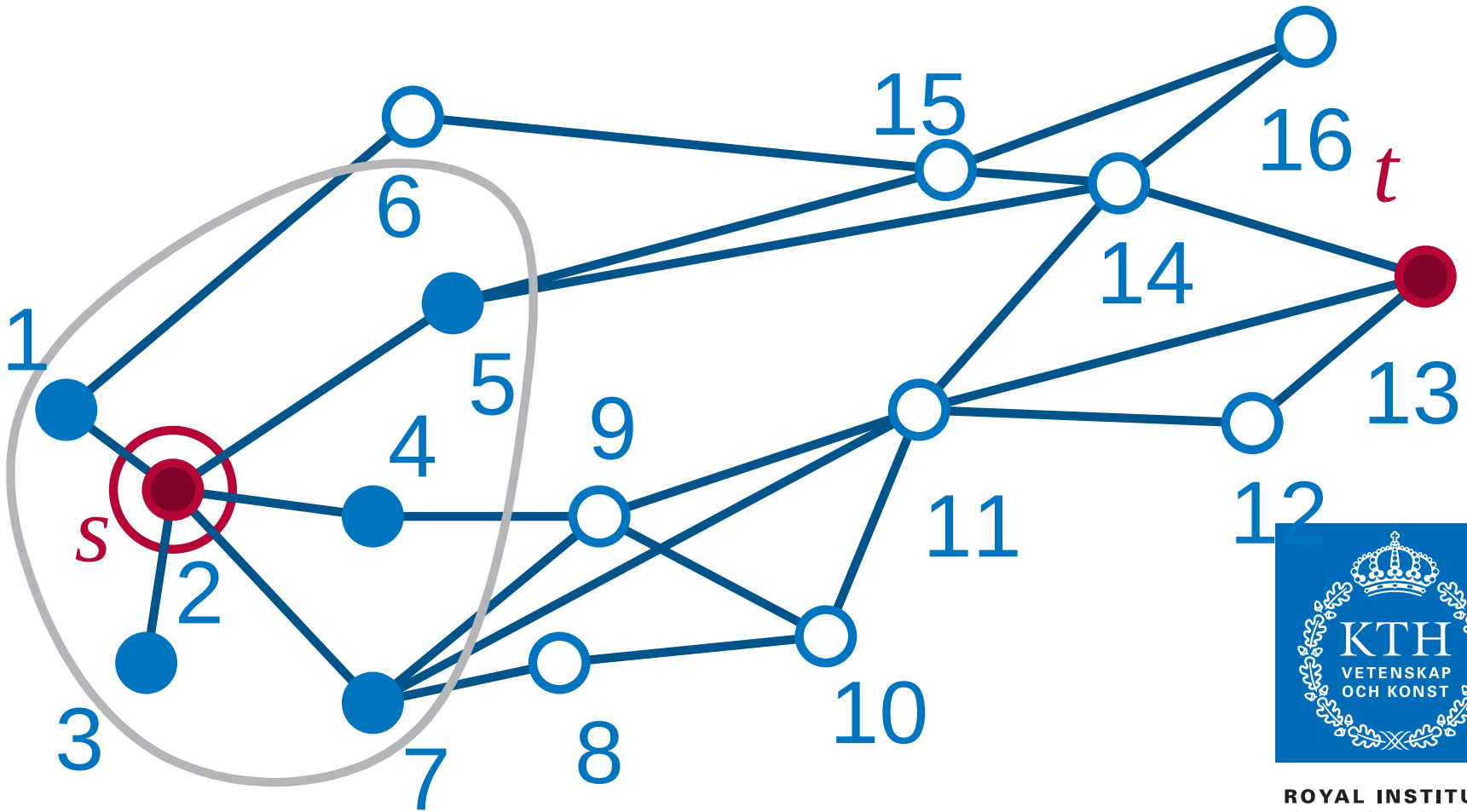
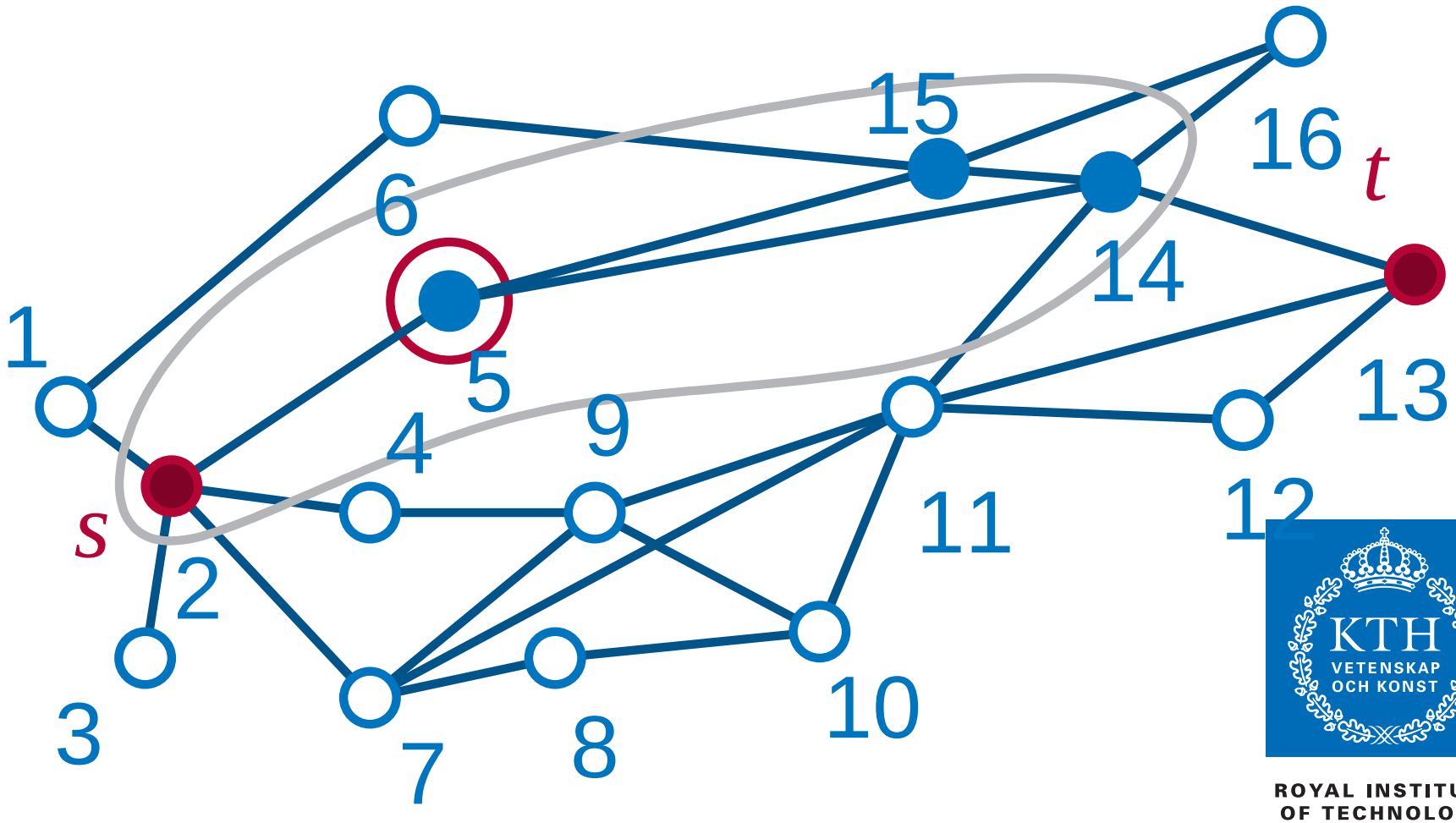
myopia



navigation



navigation



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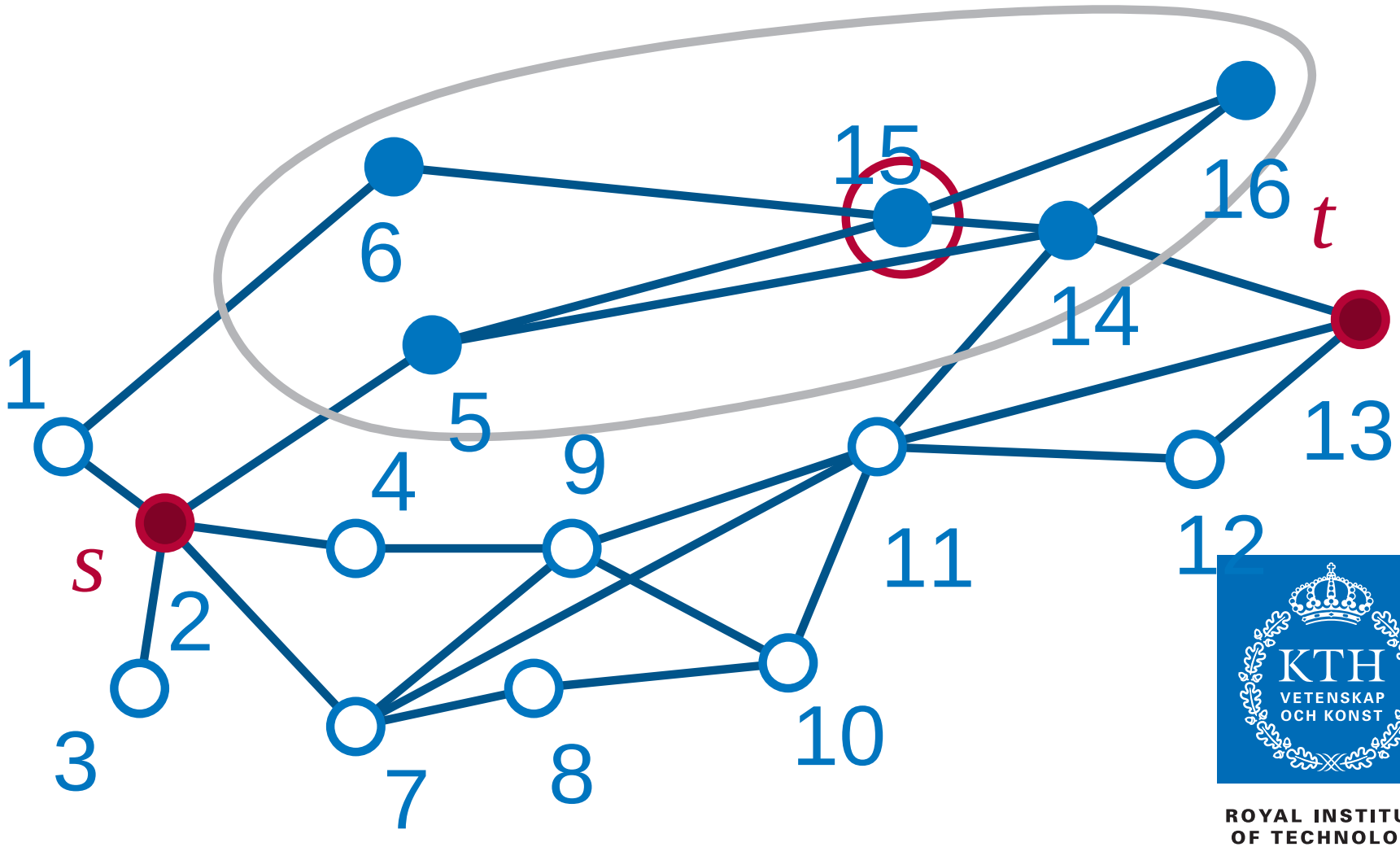

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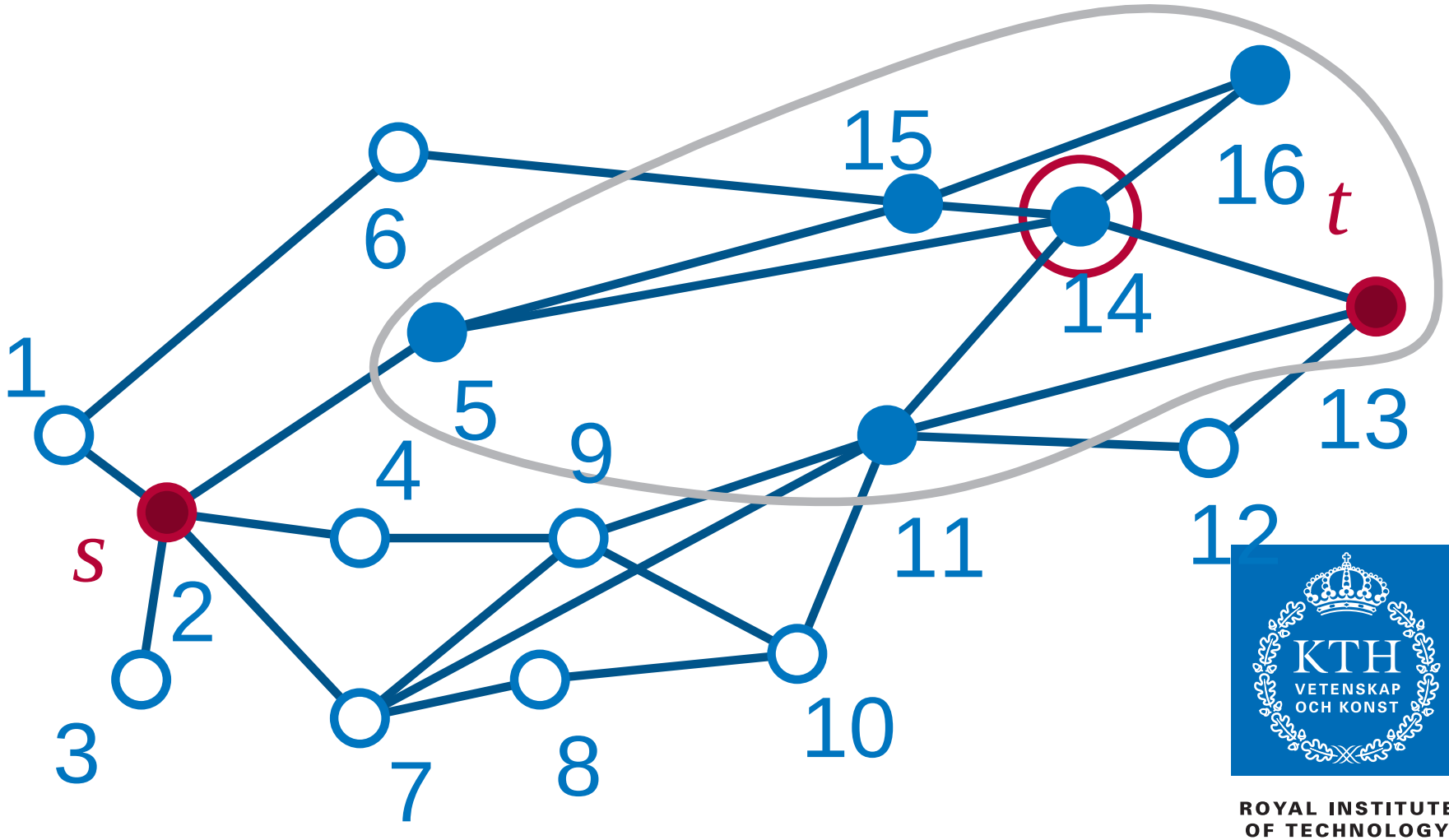

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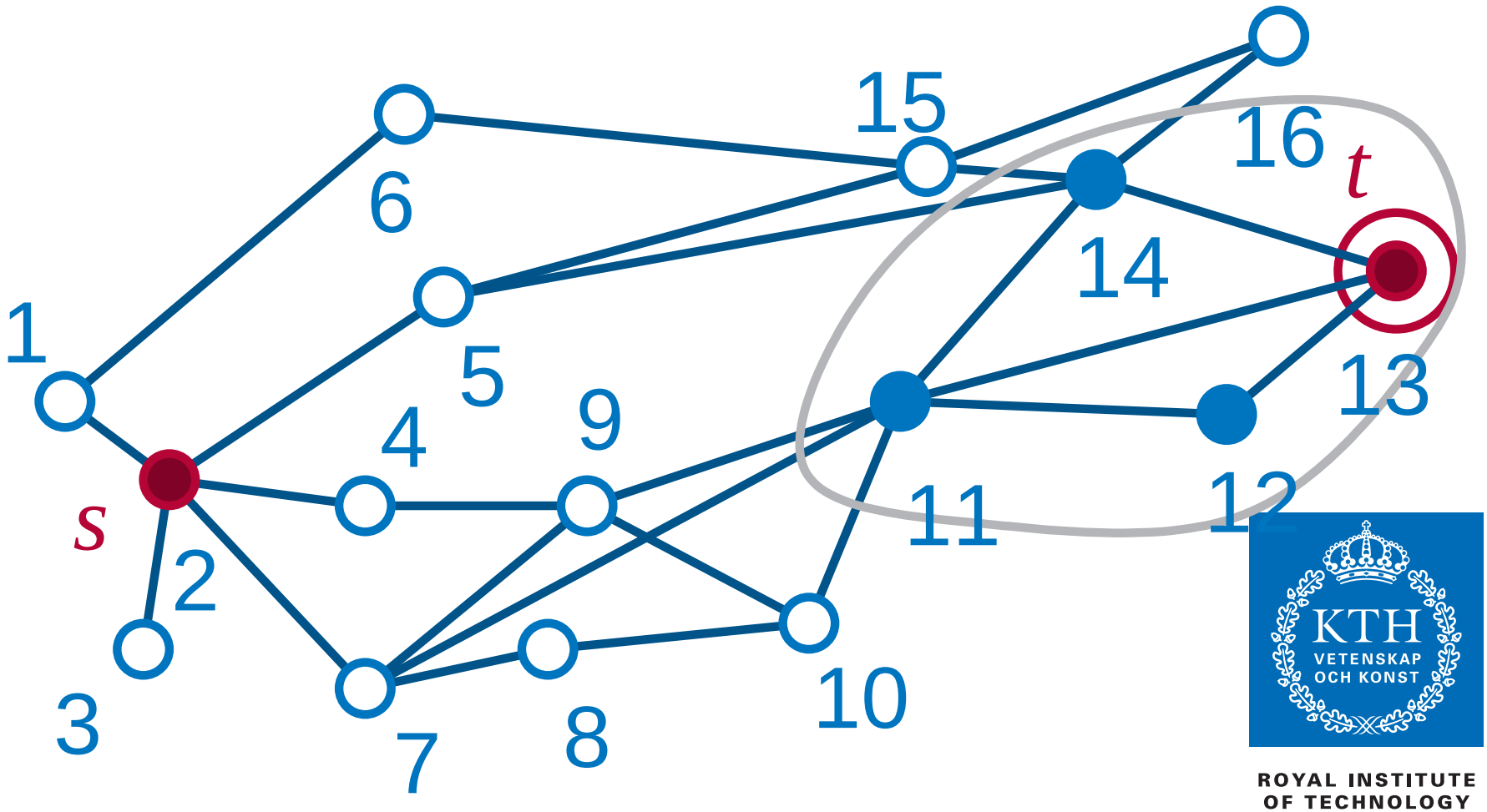

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the problem: summary

- a (static) graph G of N vertices
- each vertex is associated with an index $1, \cdots, N$
- packets are created with source s and destination t
- packets have memory, but no previous knowledge of the graph
- packets can observe the neighborhood of their present location
- how can we chose the indices, and a packet navigation algorithm, so that the average effective distance, or *transit time* τ, is minimized?

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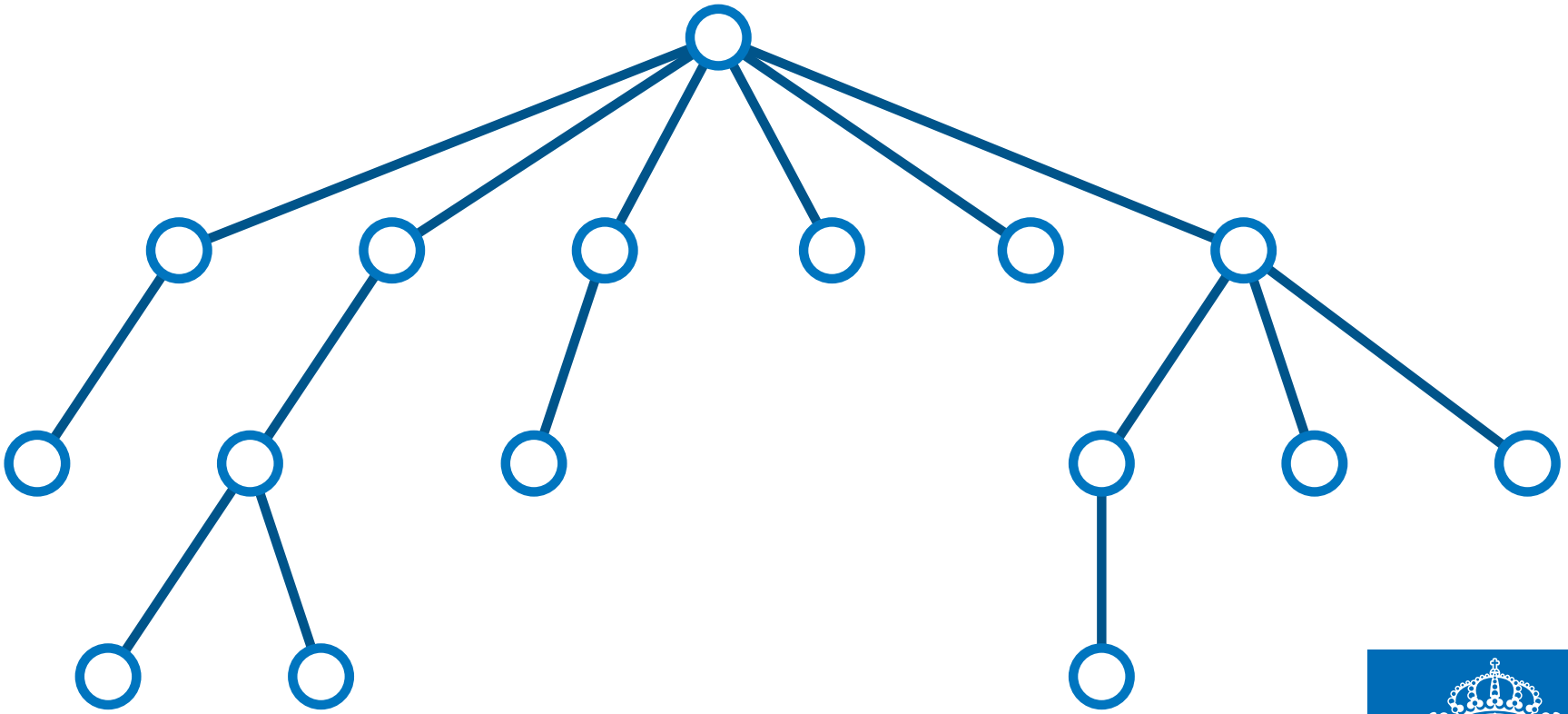
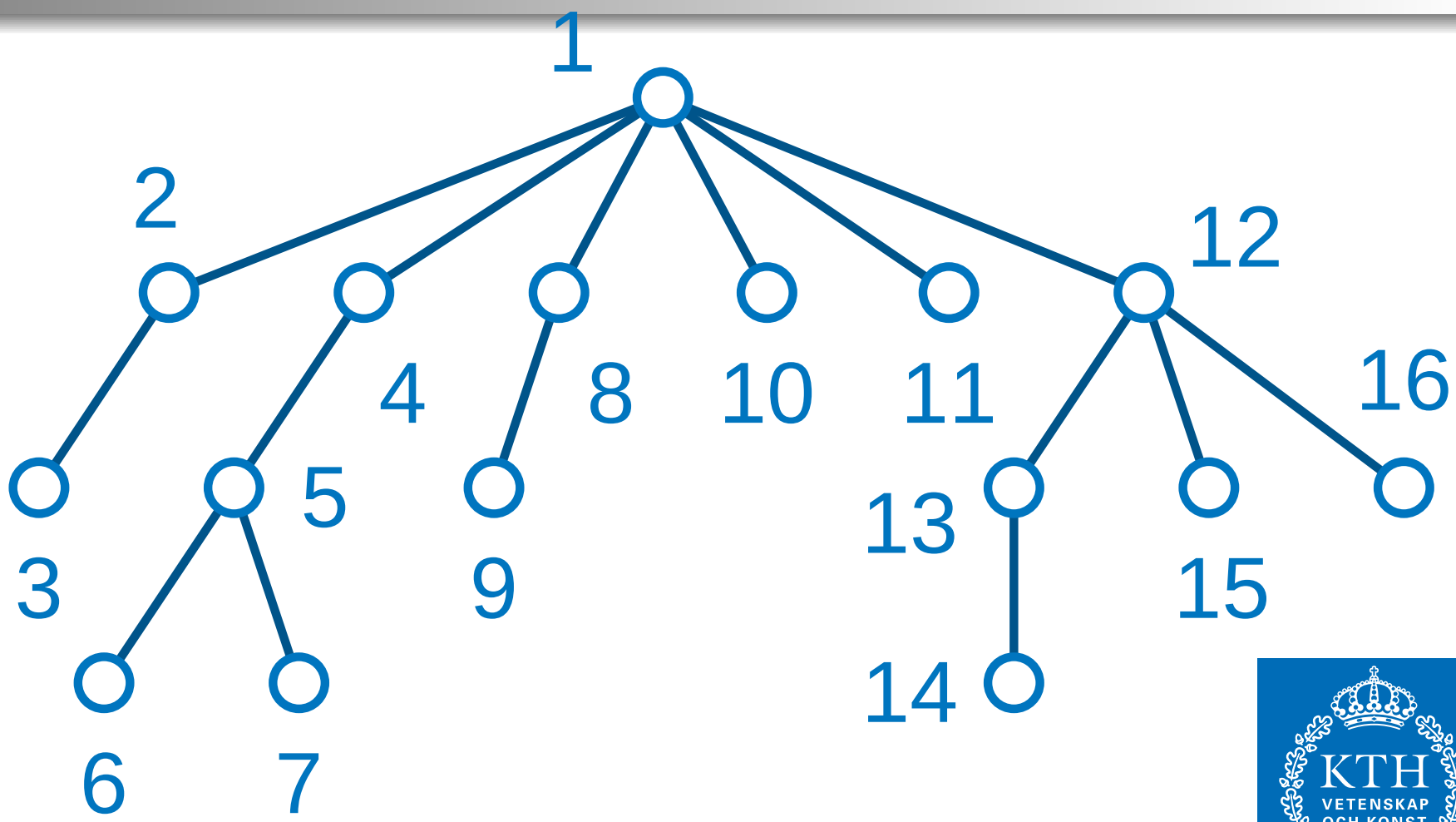
a tree



search tree



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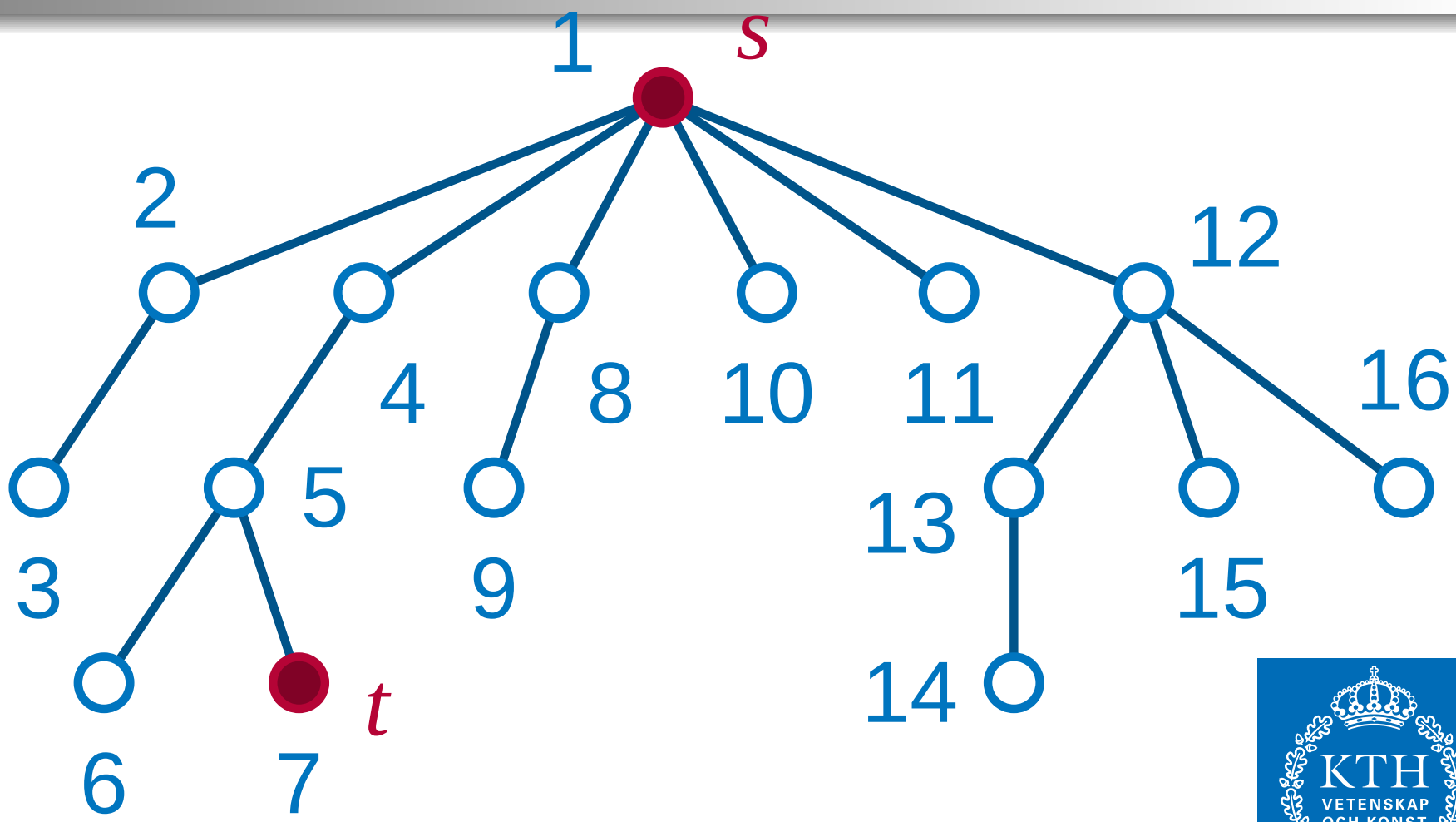

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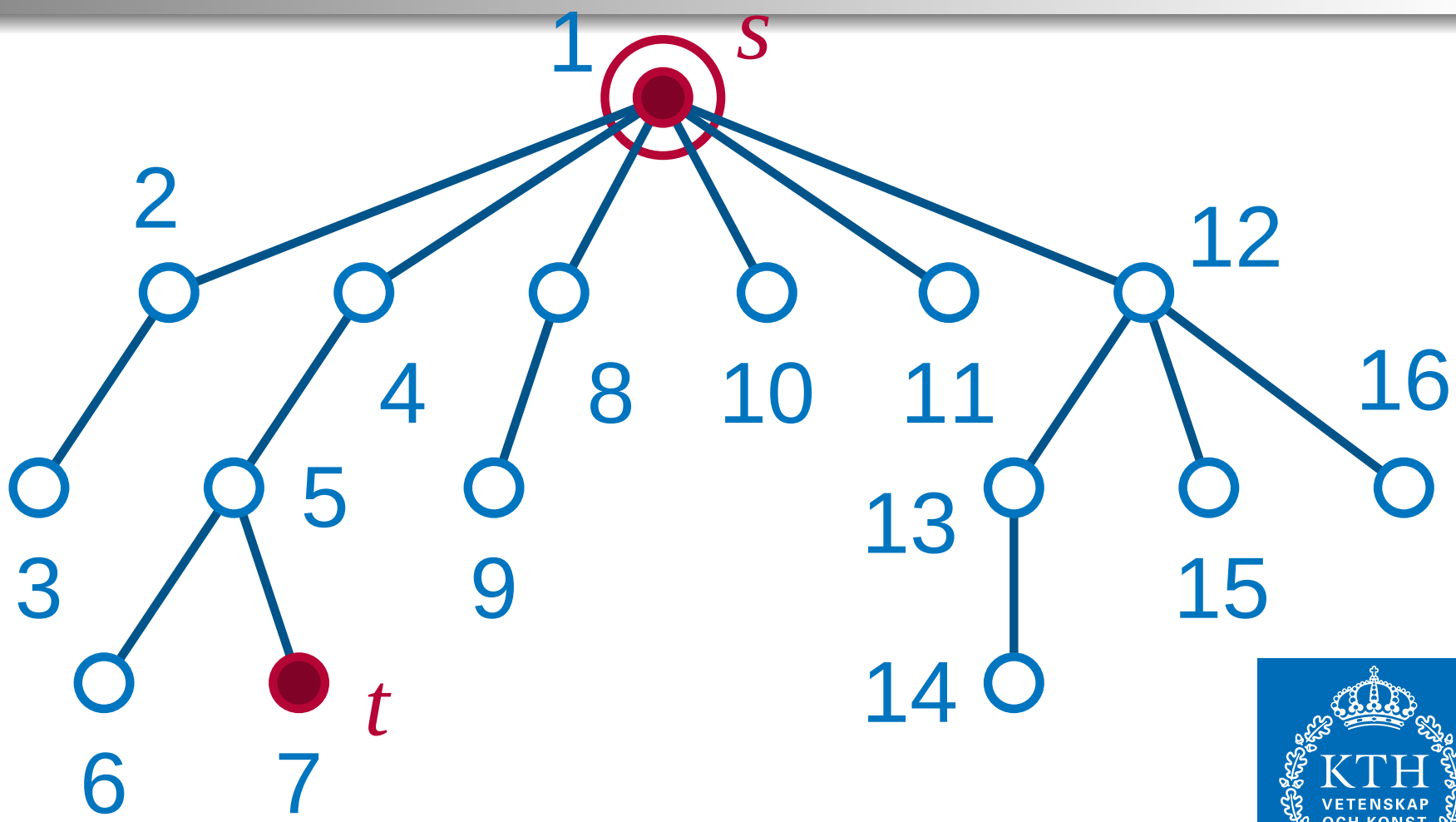

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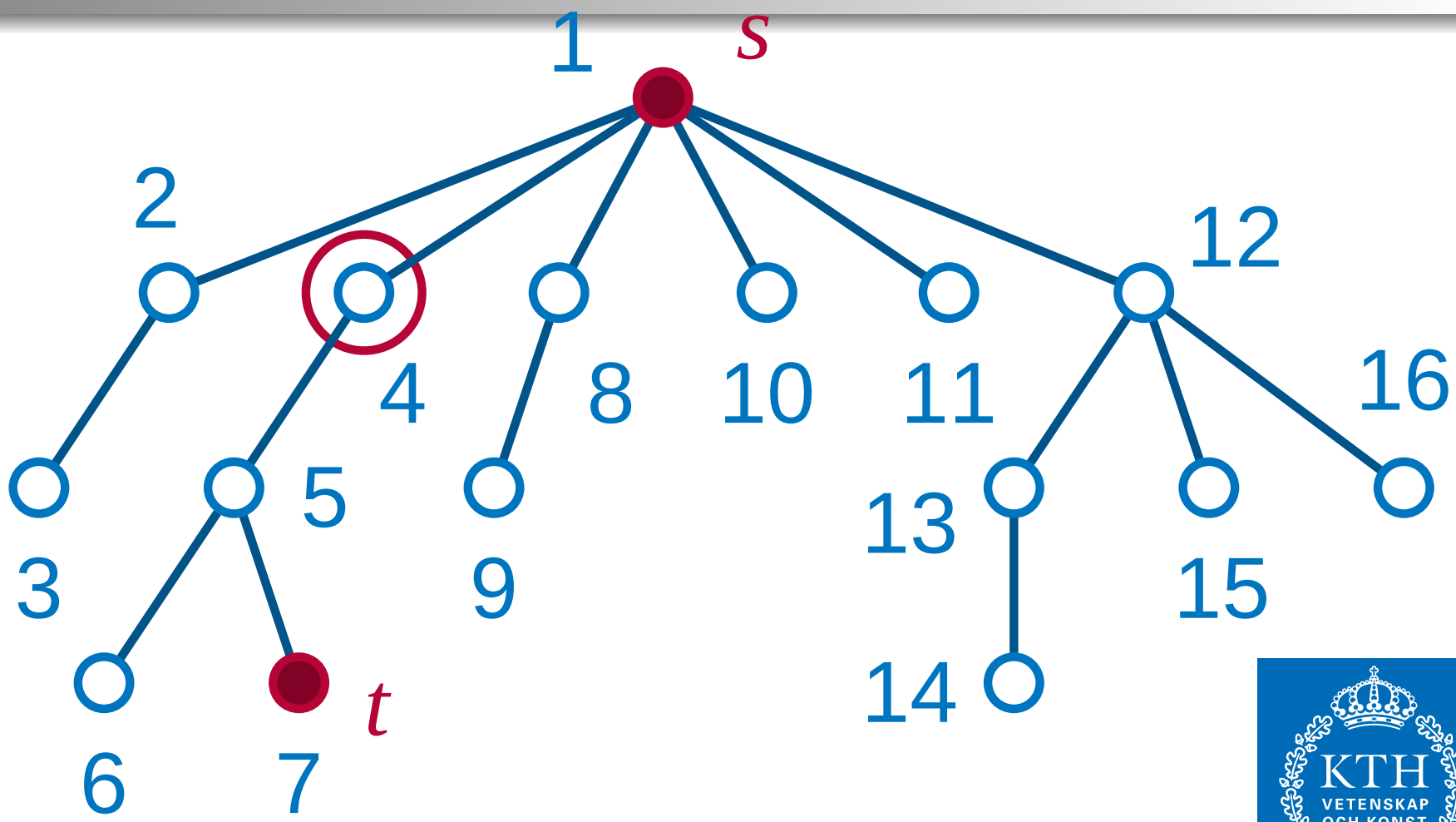

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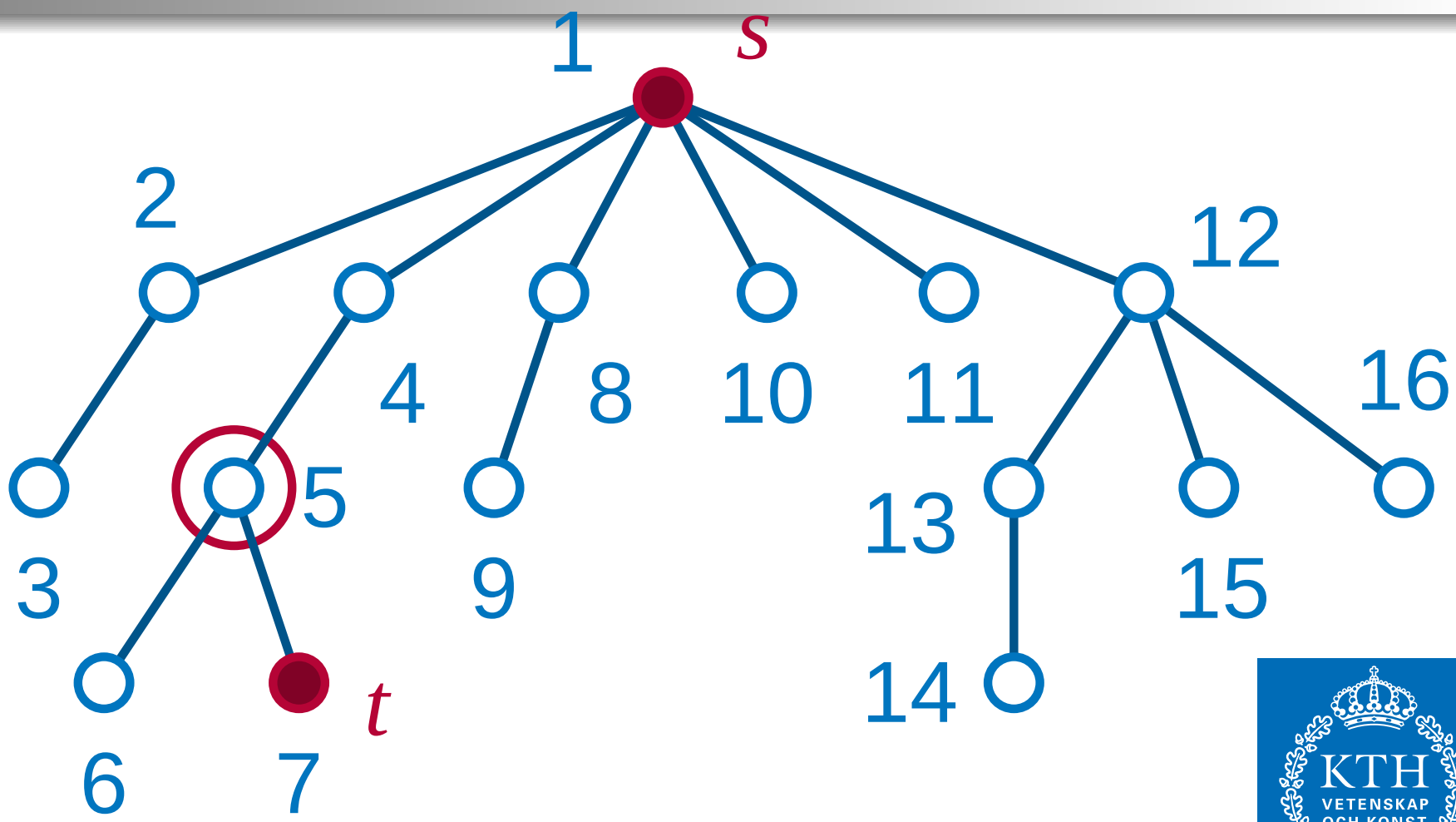

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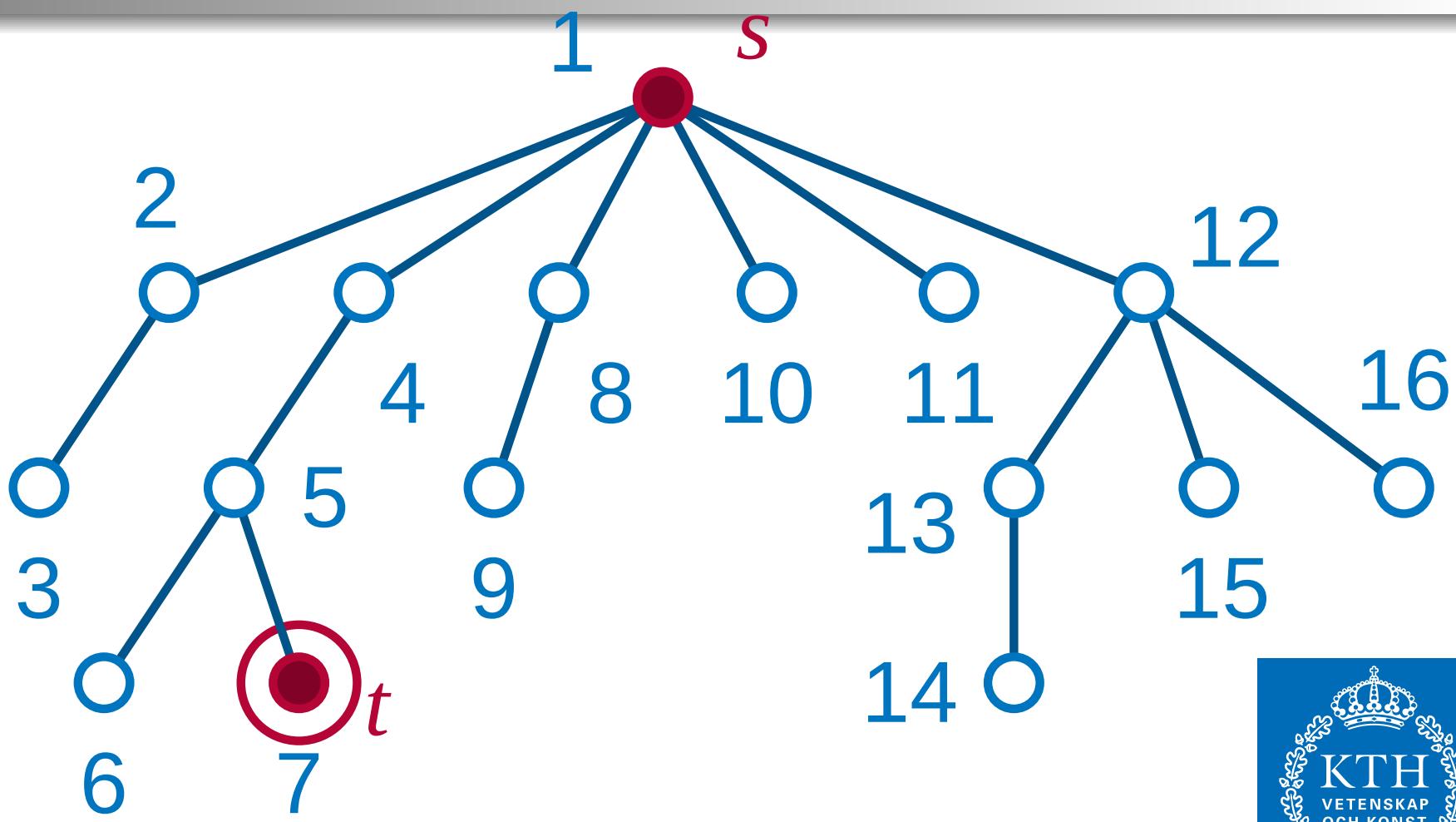

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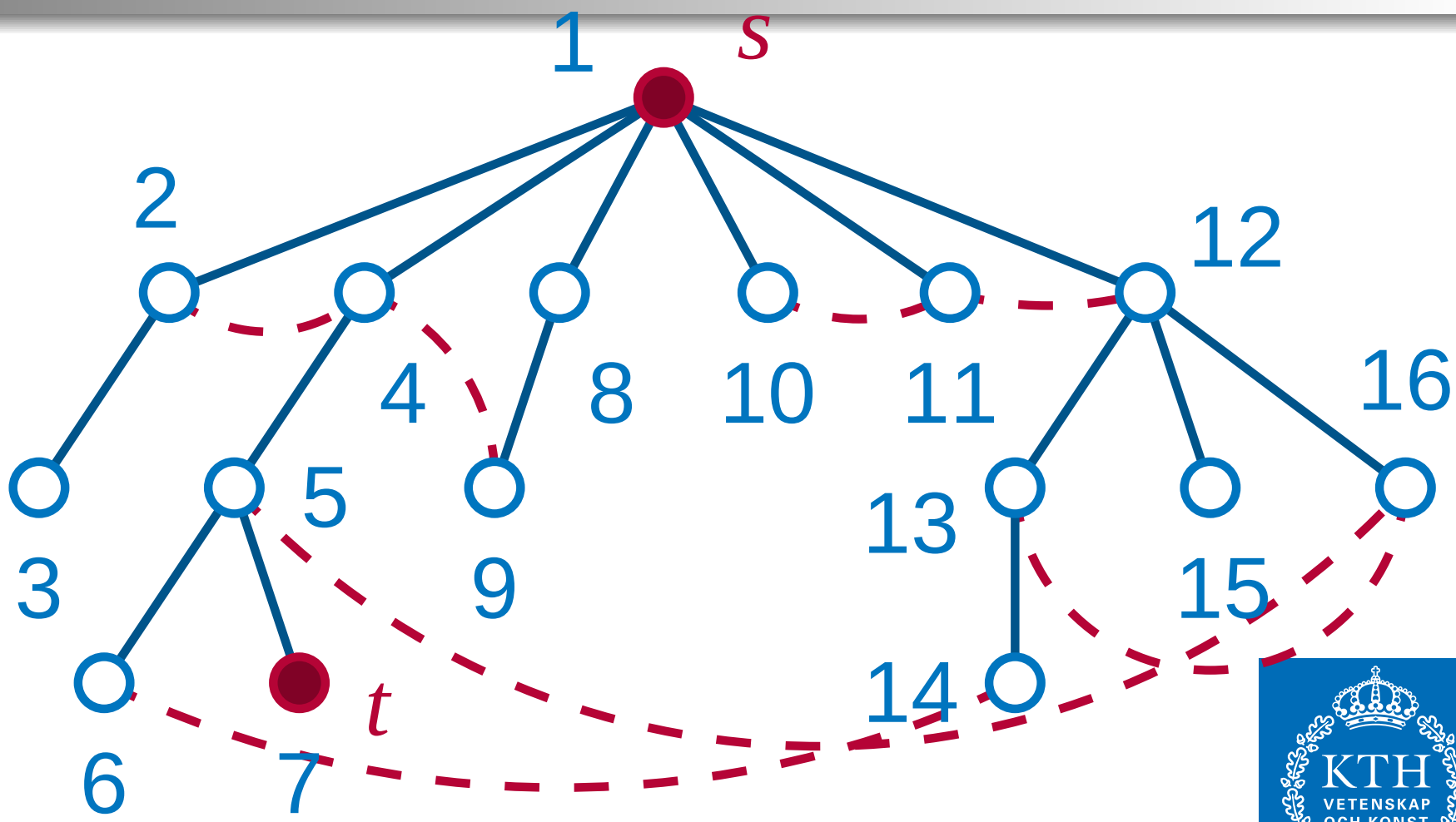
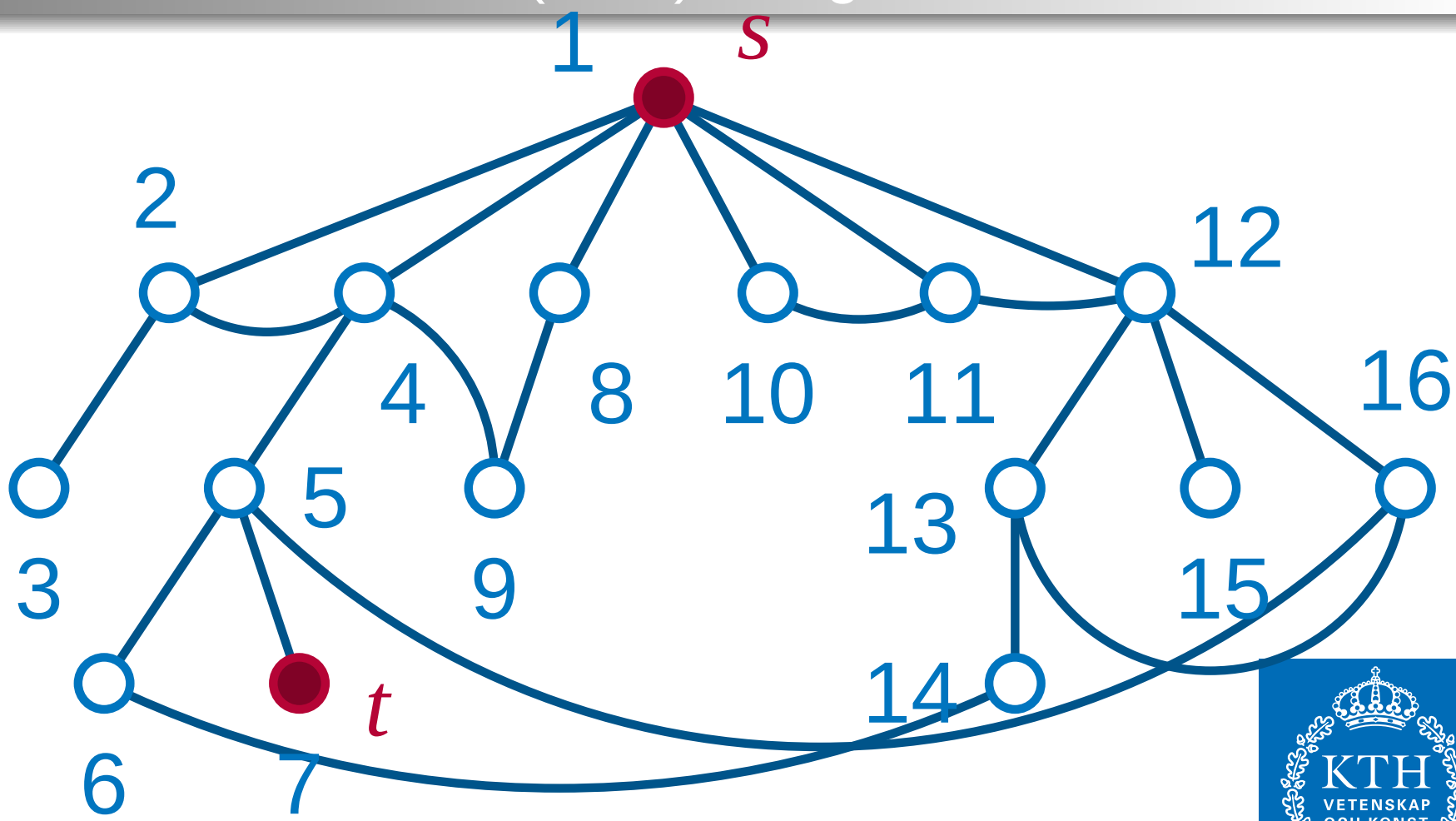


accurate search down (ASD) navigation



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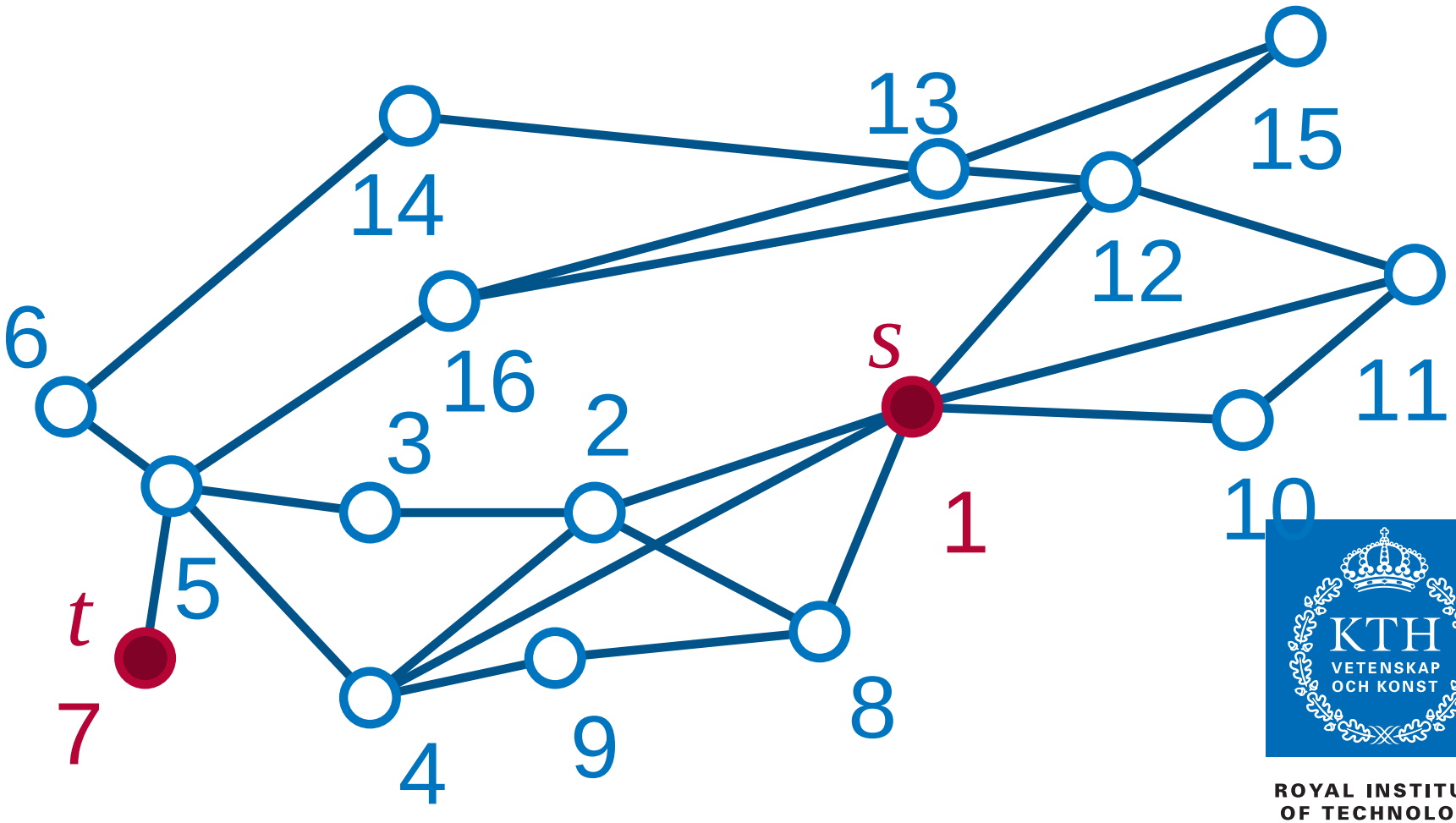

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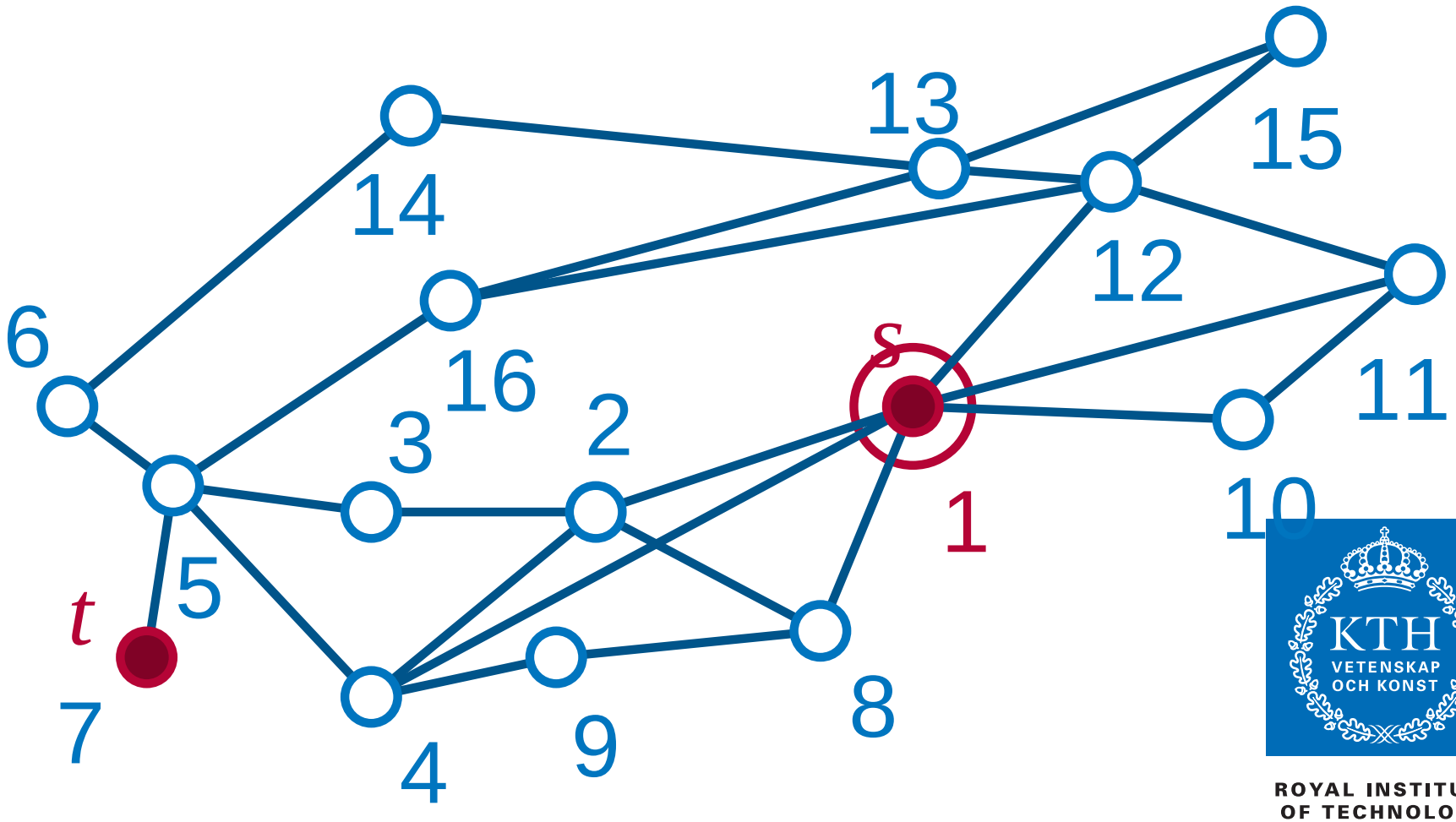

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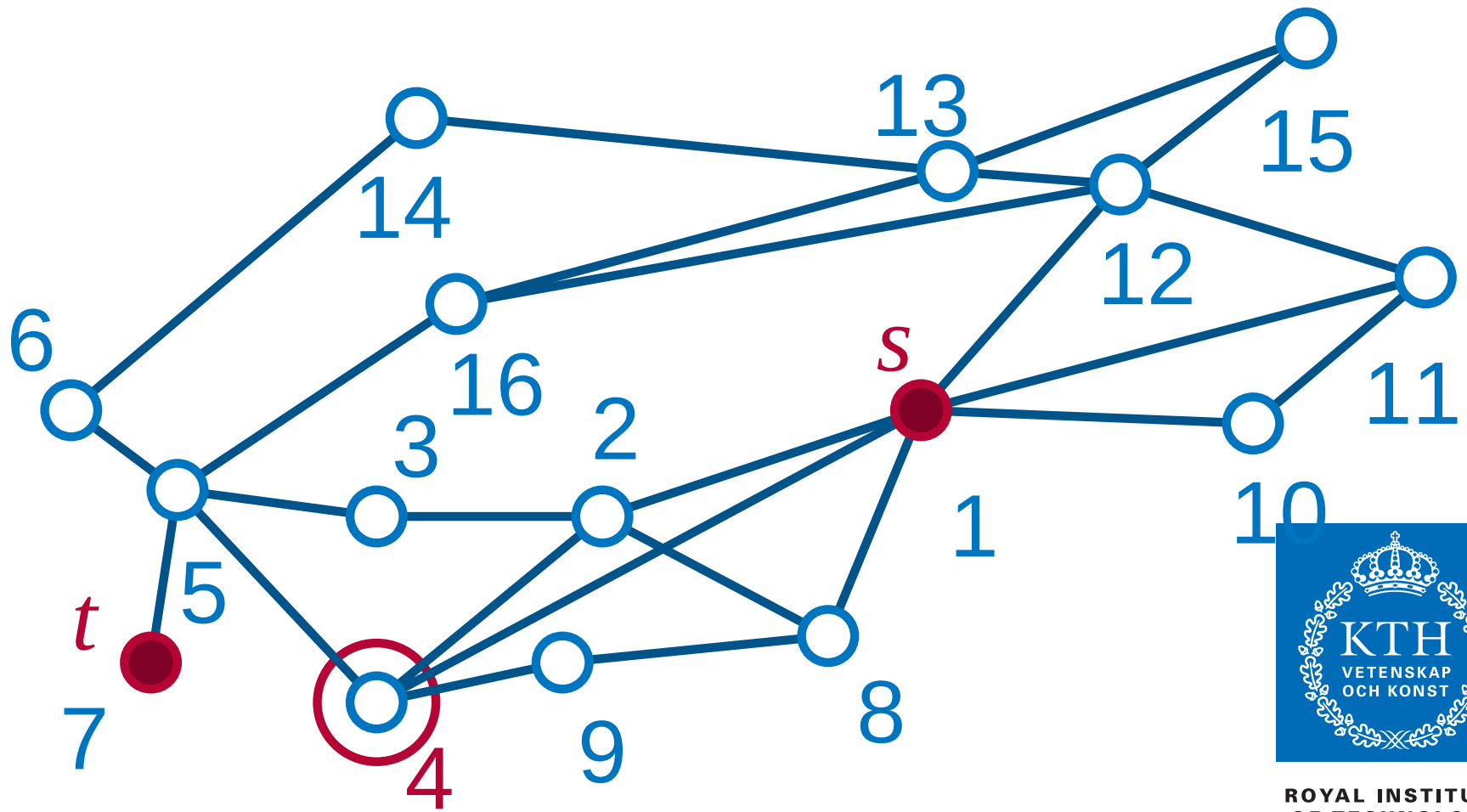

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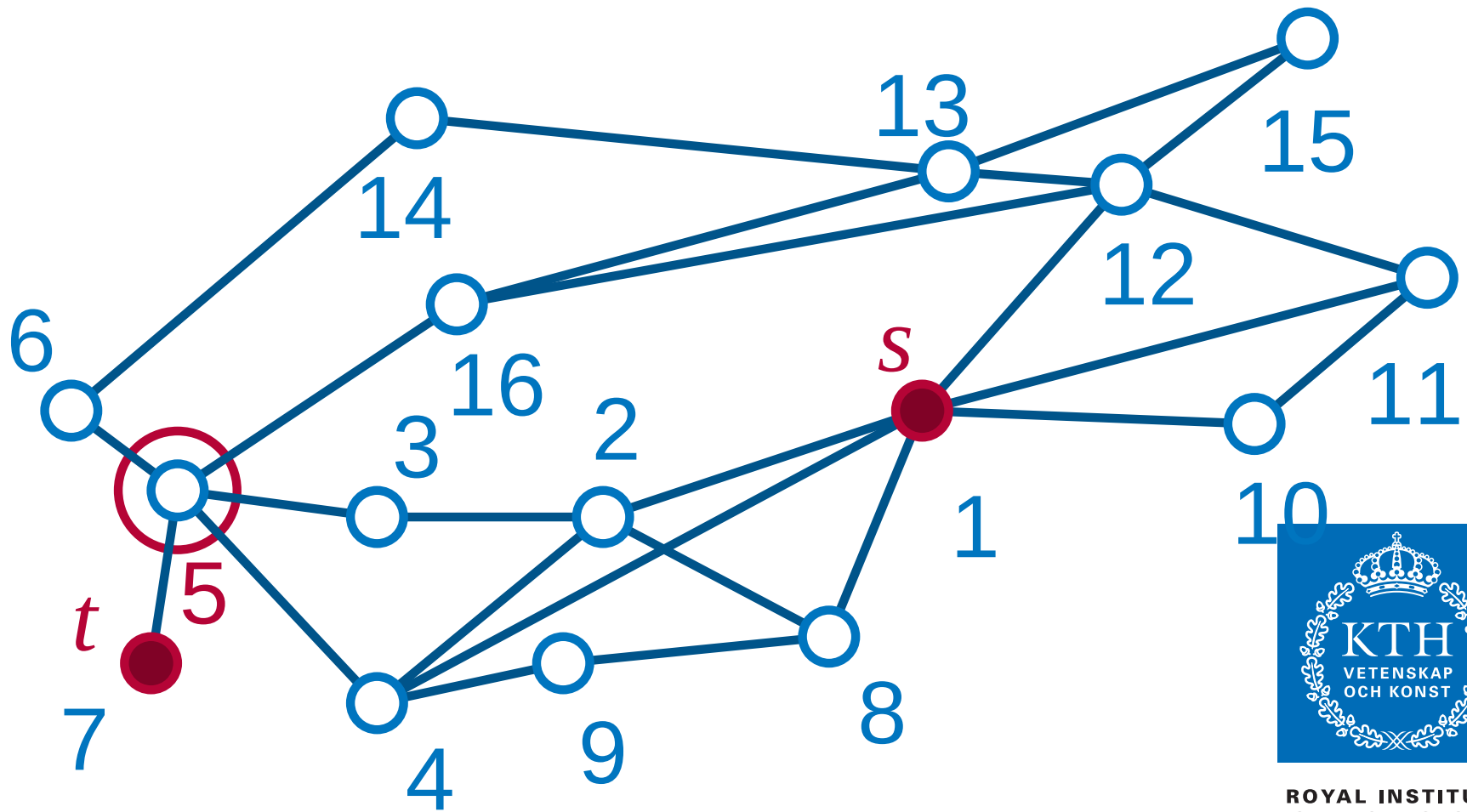

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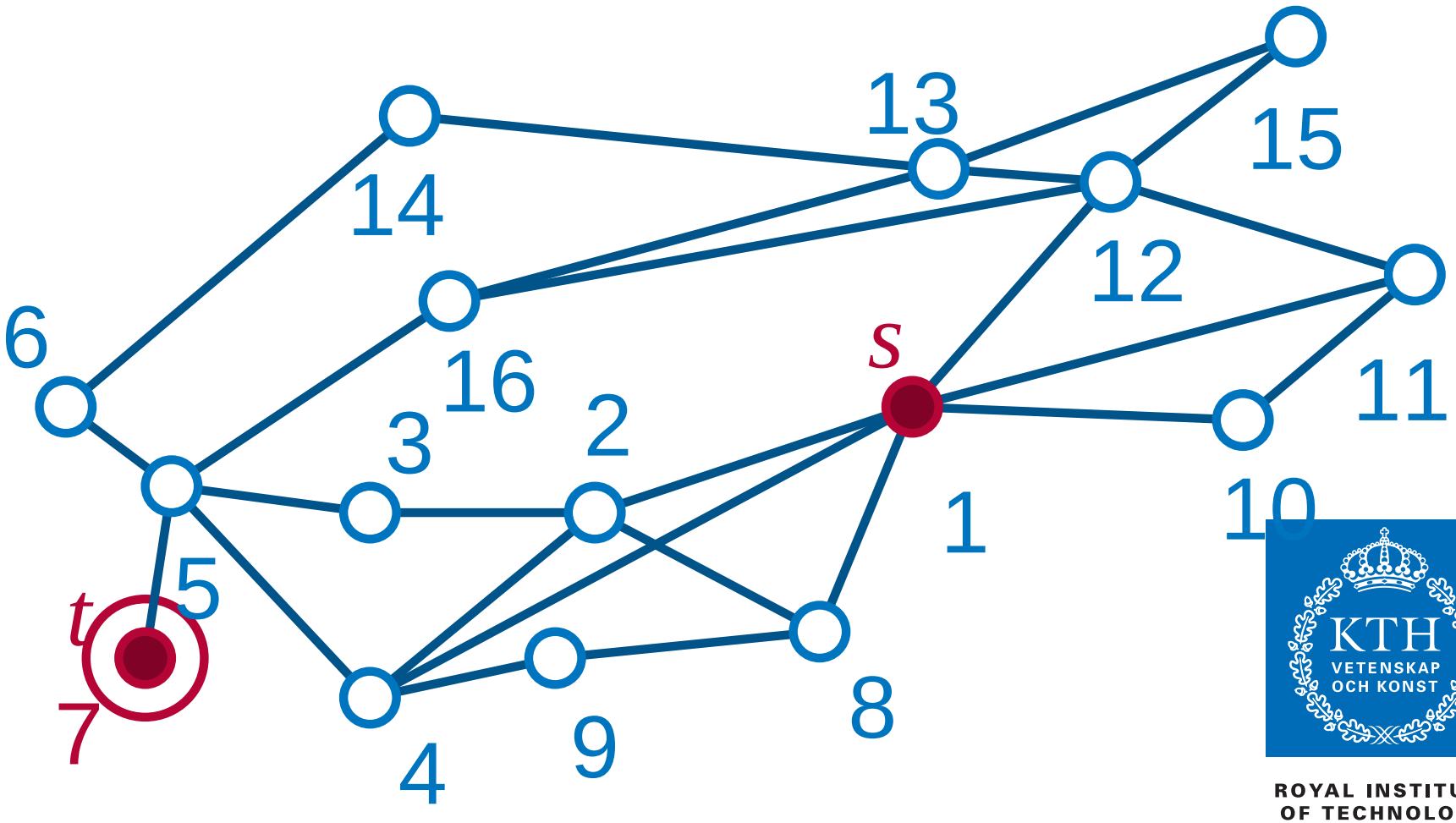

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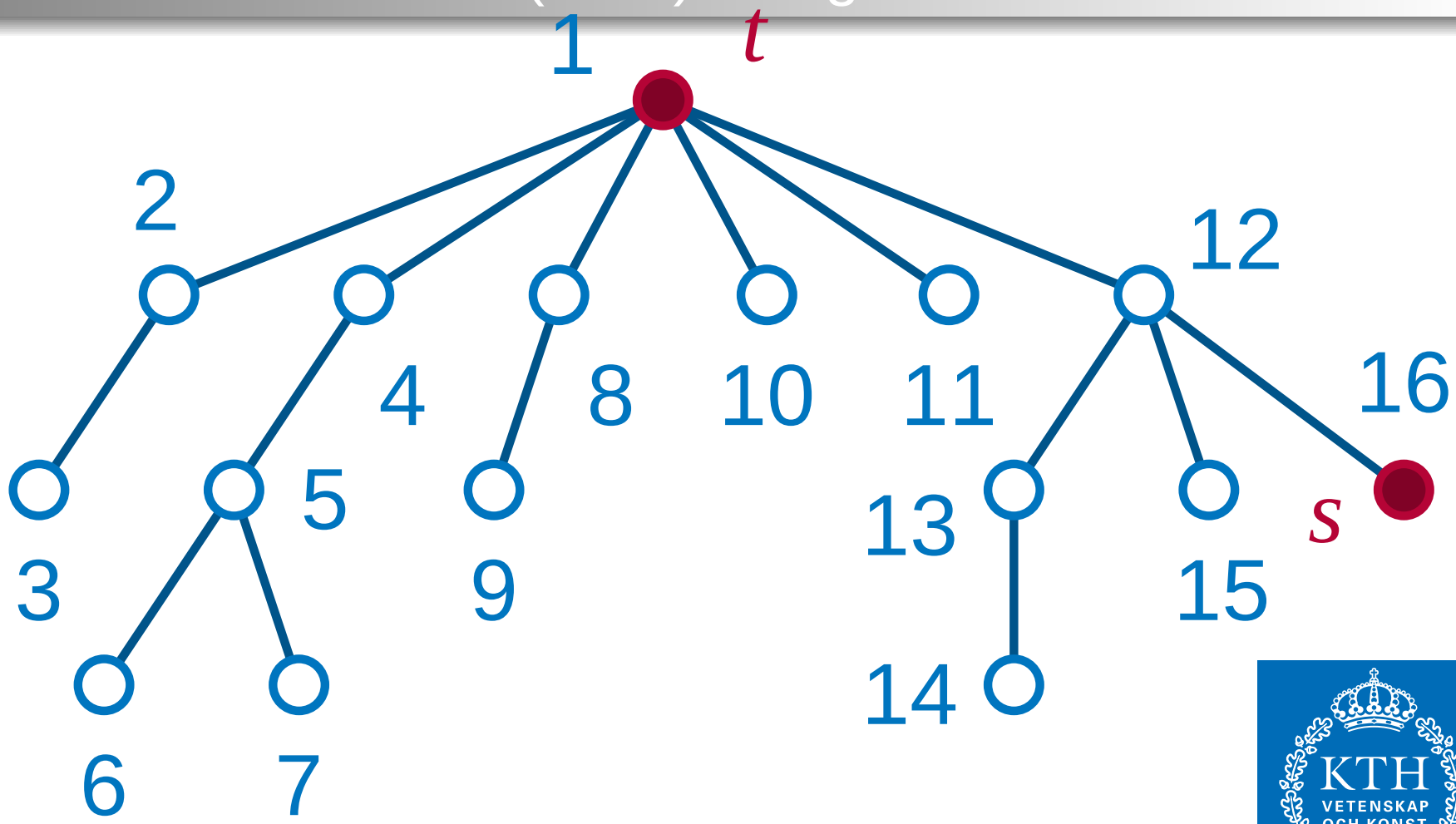

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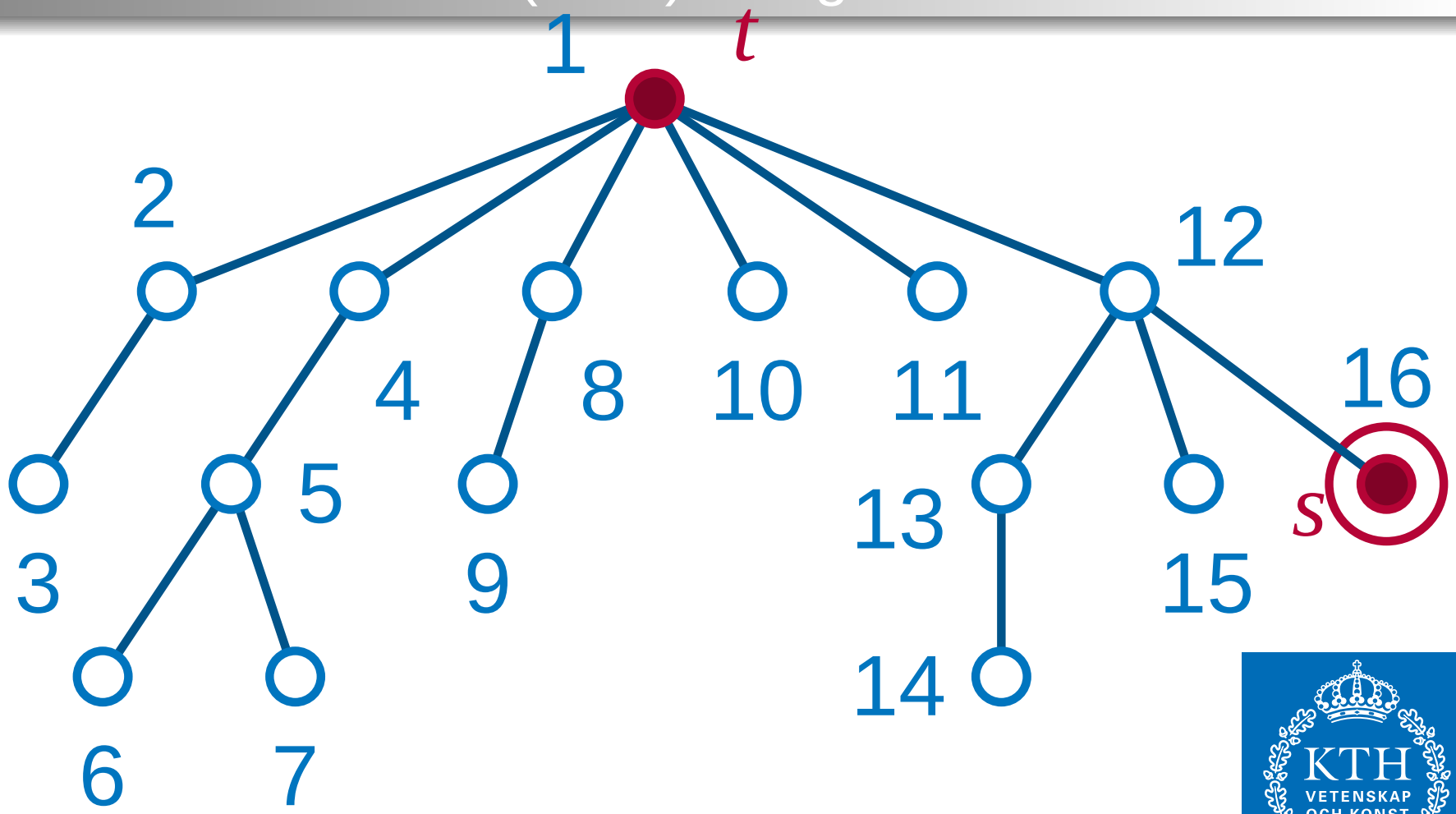

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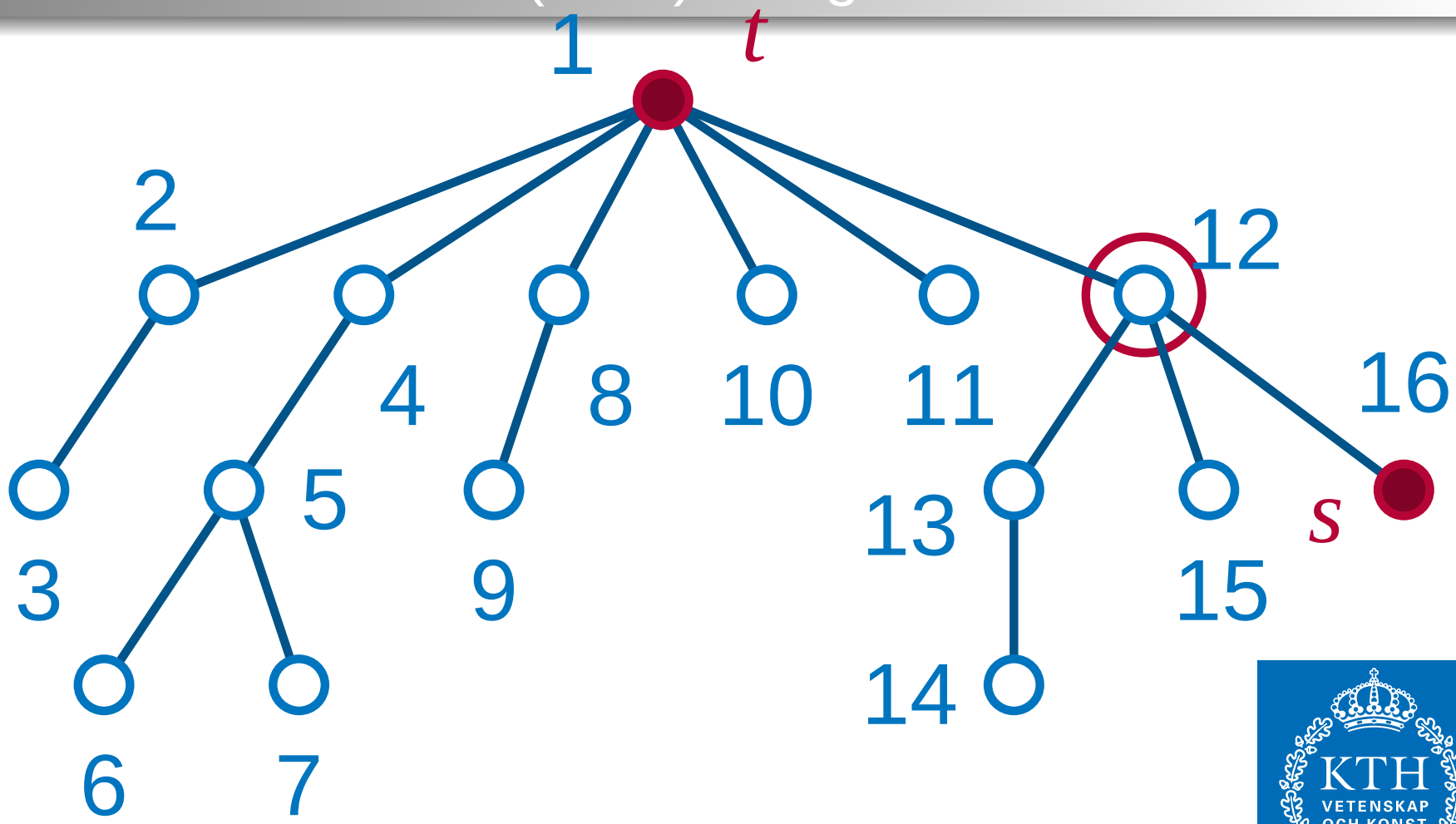

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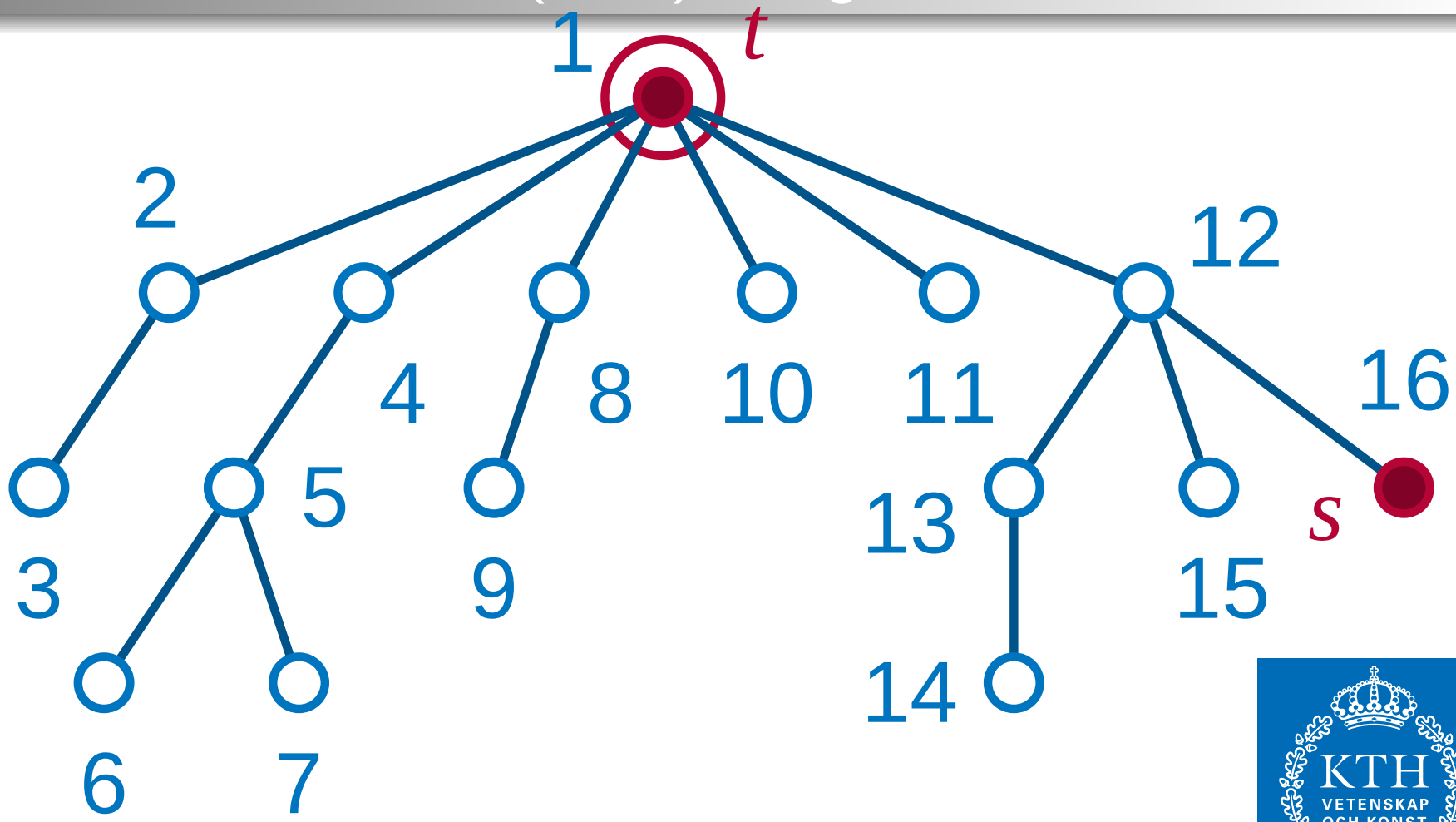

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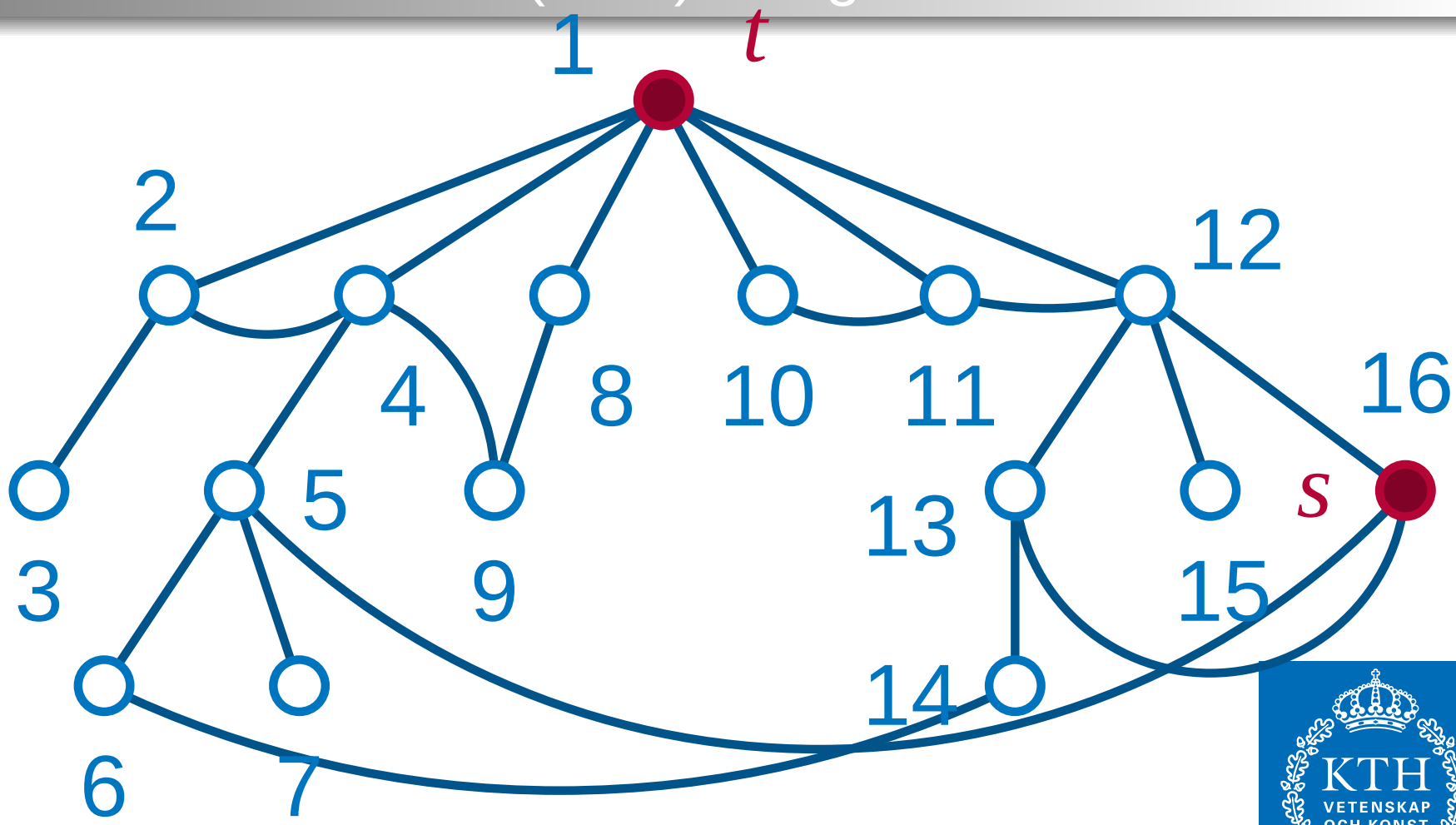

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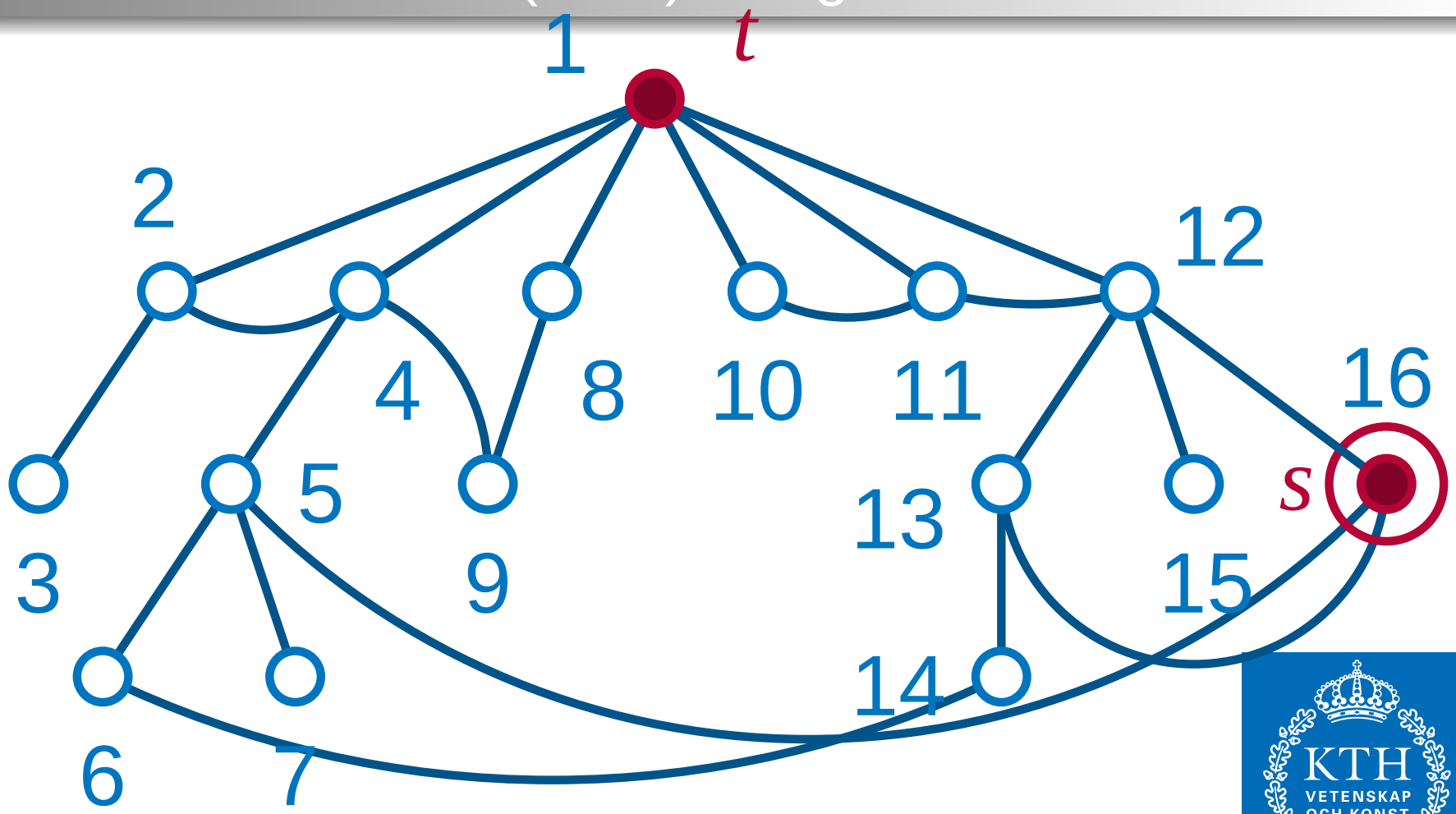

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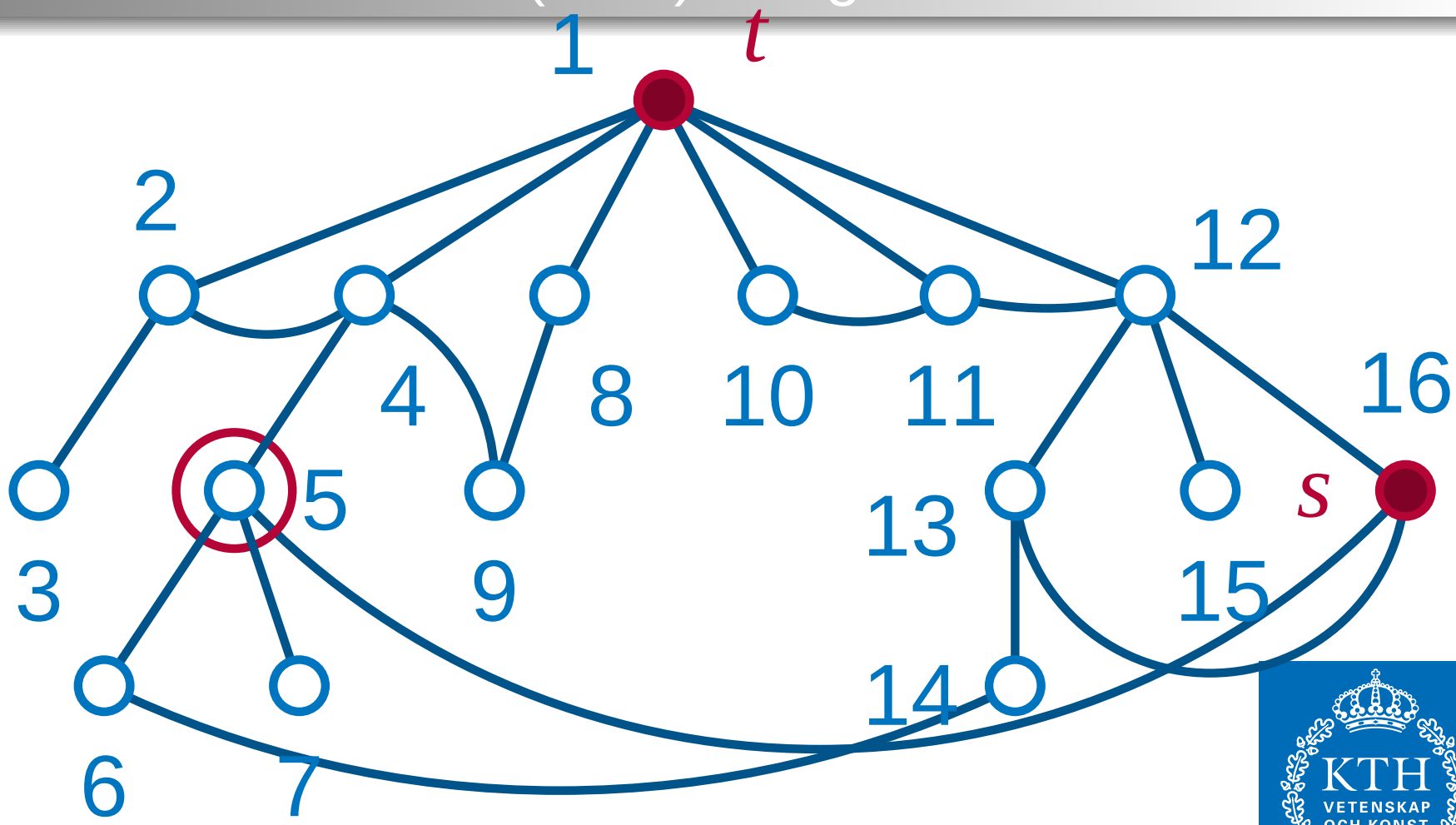

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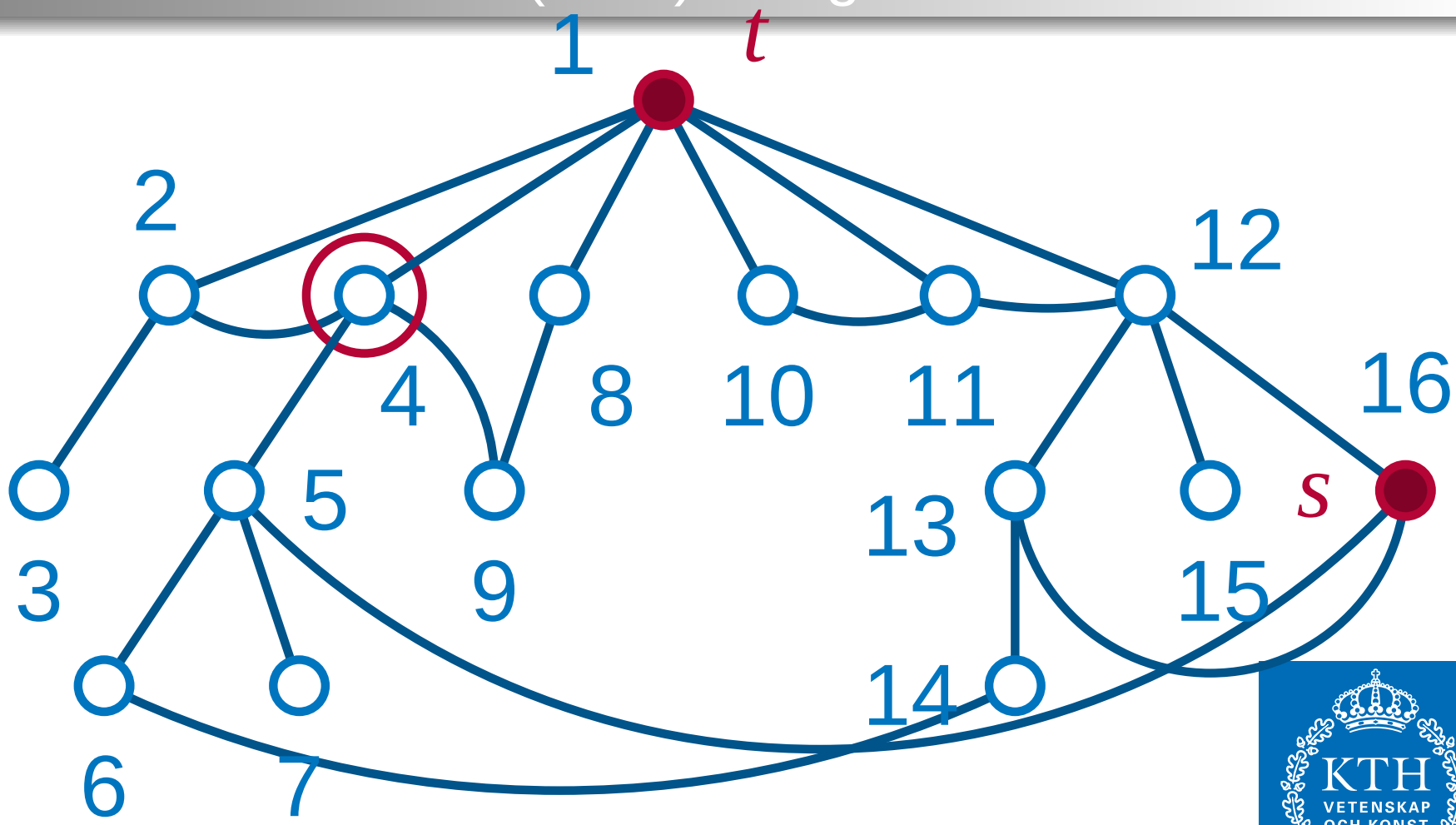

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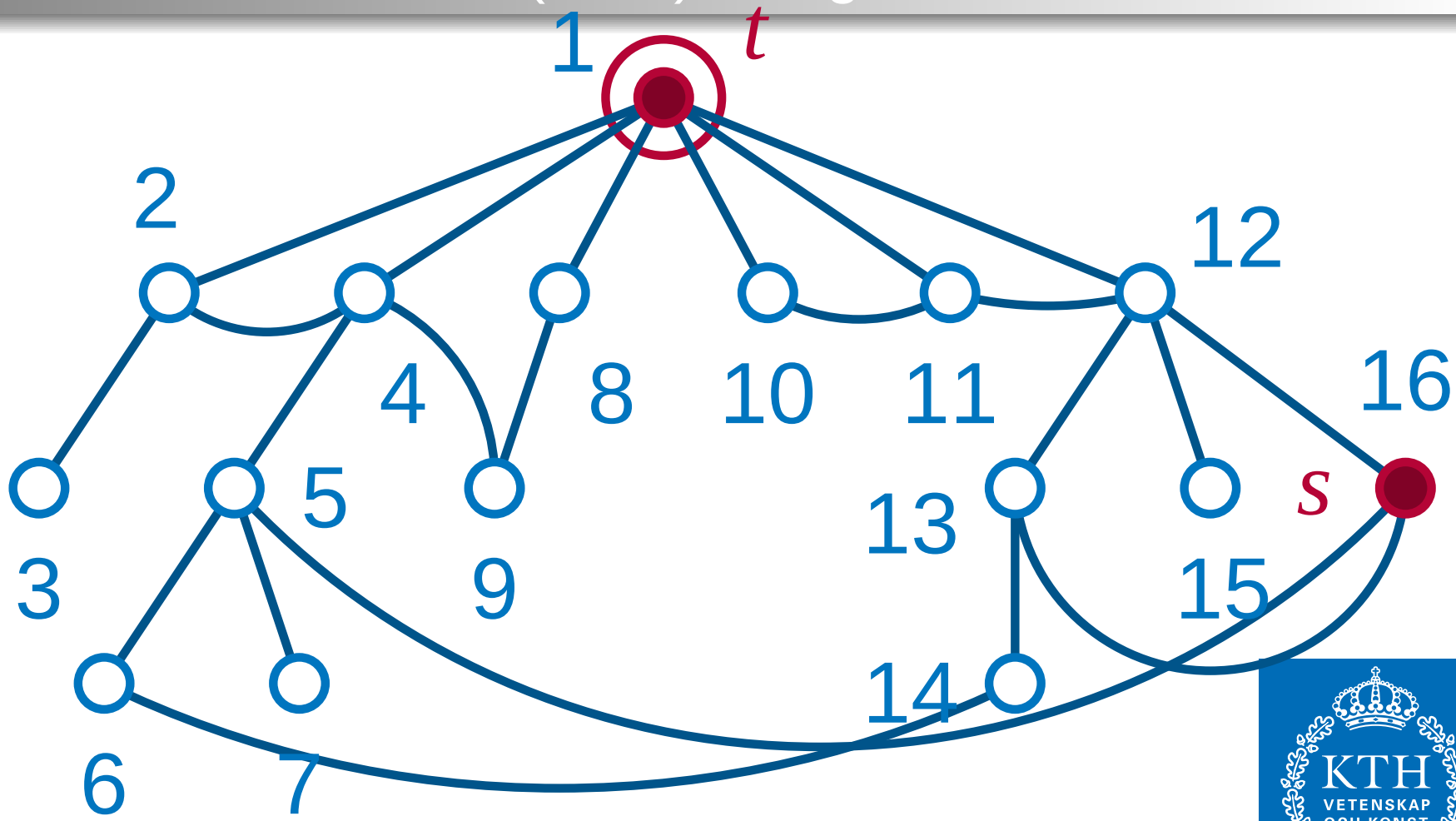

accurate search down (ASD) indexing

- choose one of the vertices with least eccentricity as root
- index the rest with a depth first search
- increment index at the first encounter of a vertex

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- first, move towards smaller indices until the root, 1, is reached
- then, move to the neighbor with largest index $\geqslant t$
- if t is in the neighborhood during the upward search, go there

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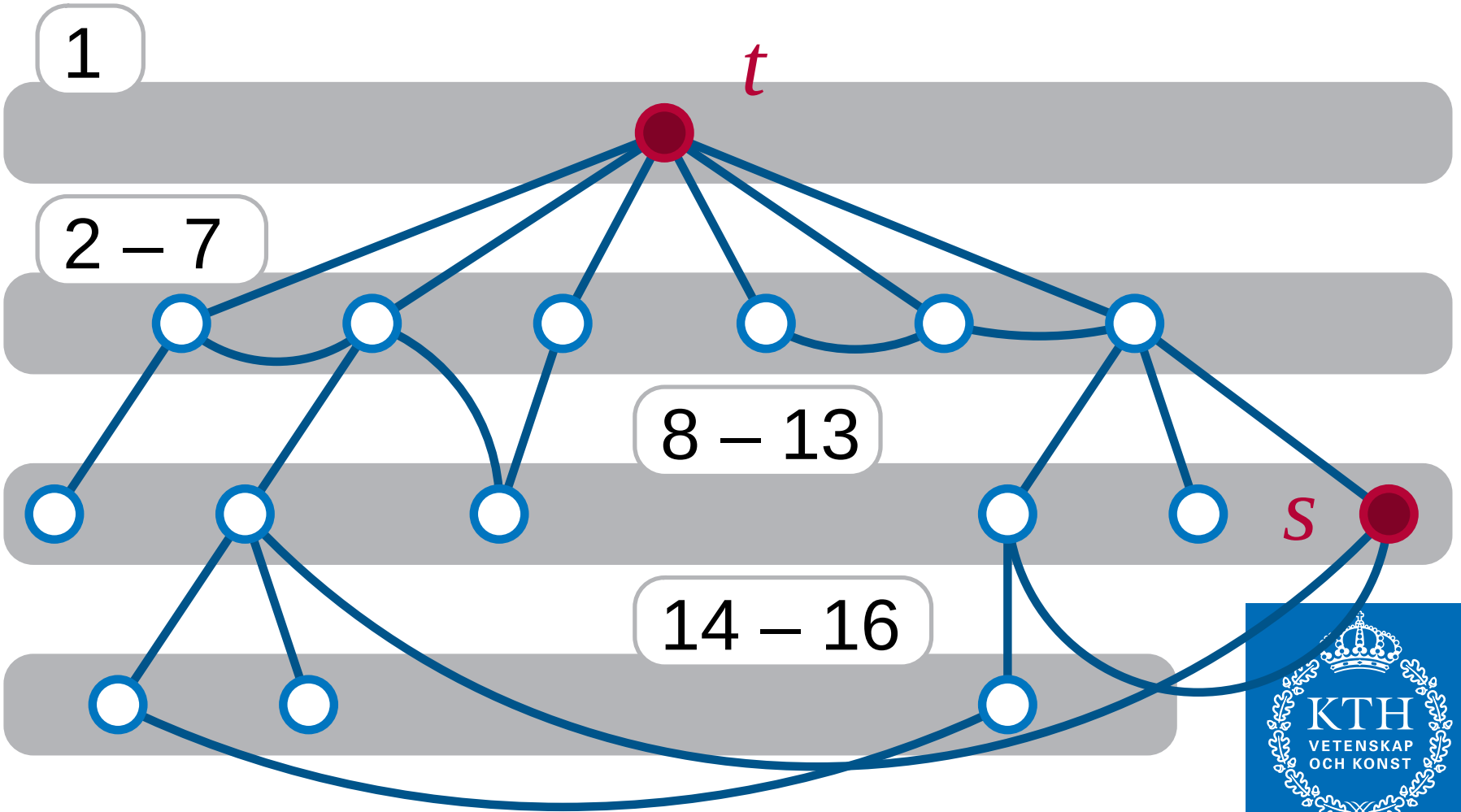
accurate search up (ACU) indexing & navigation



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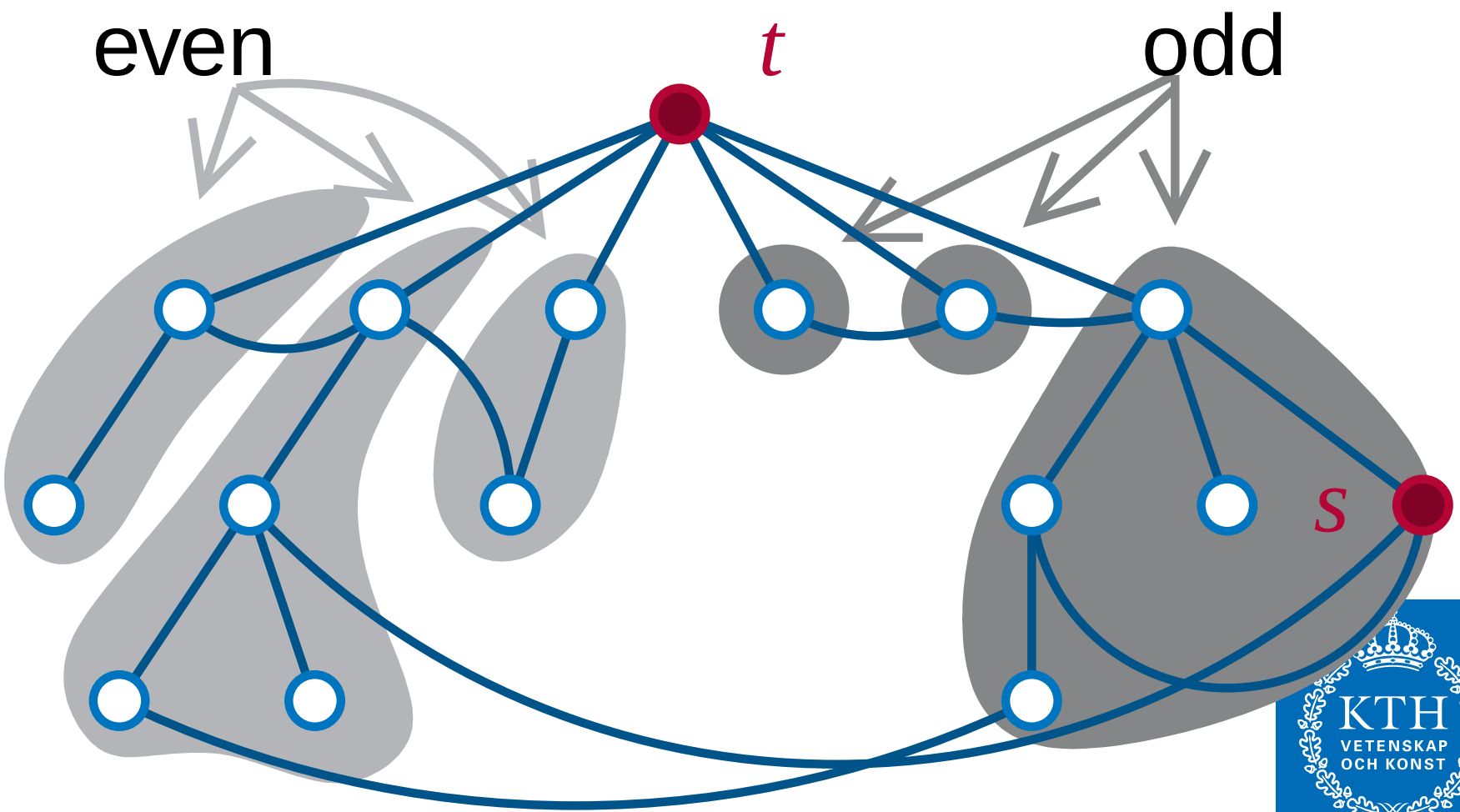

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random navigation

- random depth first search
- if t is in the neighborhood, go there

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random navigation

- random depth first search
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degree biased navigation

- depth first search in order of degree
- if t is in the neighborhood, go there

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Network models

- **Barabási–Albert model** Power-law degree distribution, vanishing clustering (fraction of triangles)
- **Holme–Kim model** Power-law degree distribution, tunable clustering
- **Erdős–Rényi** Poisson degree distribution, vanishing clustering
- **Square grid**

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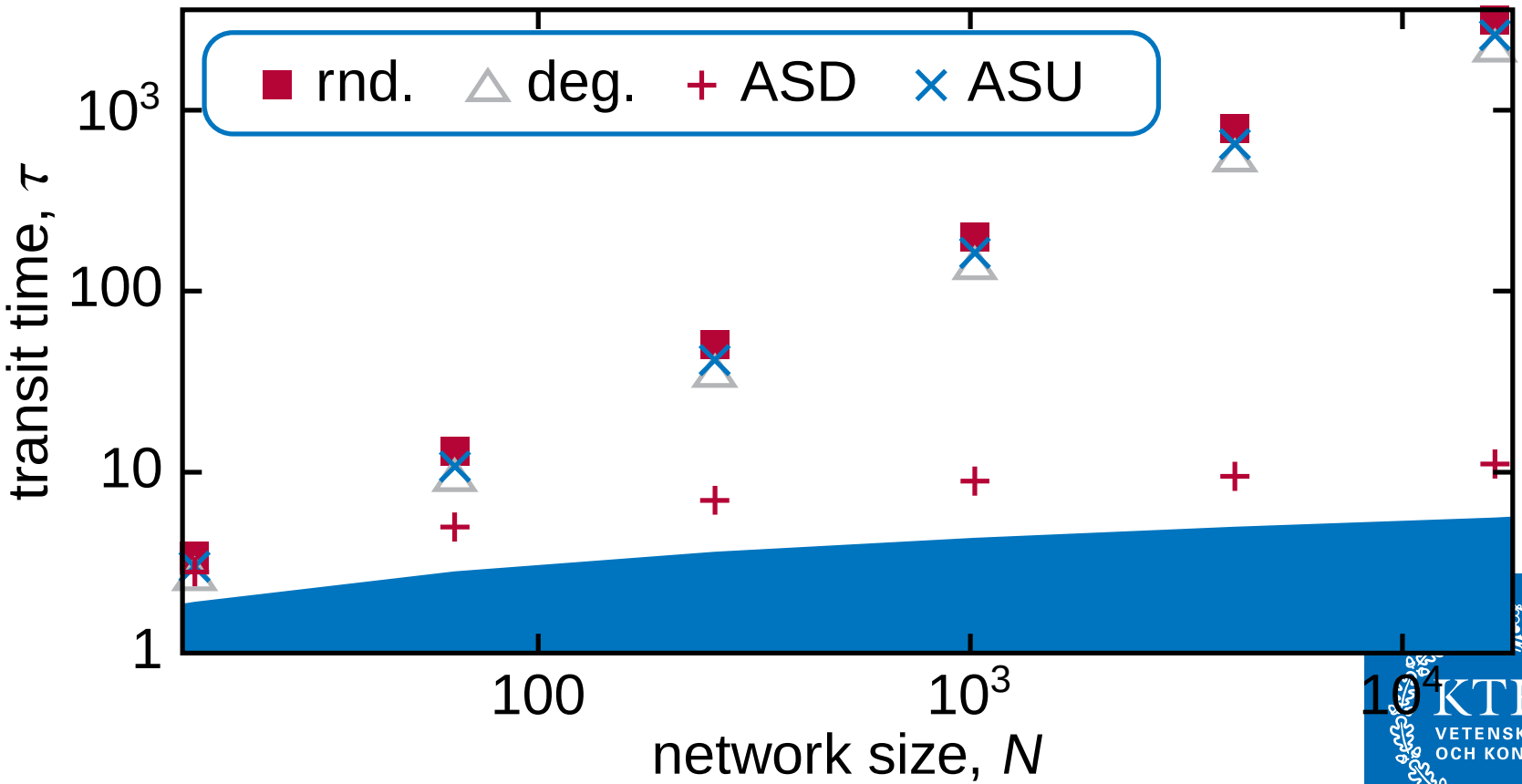
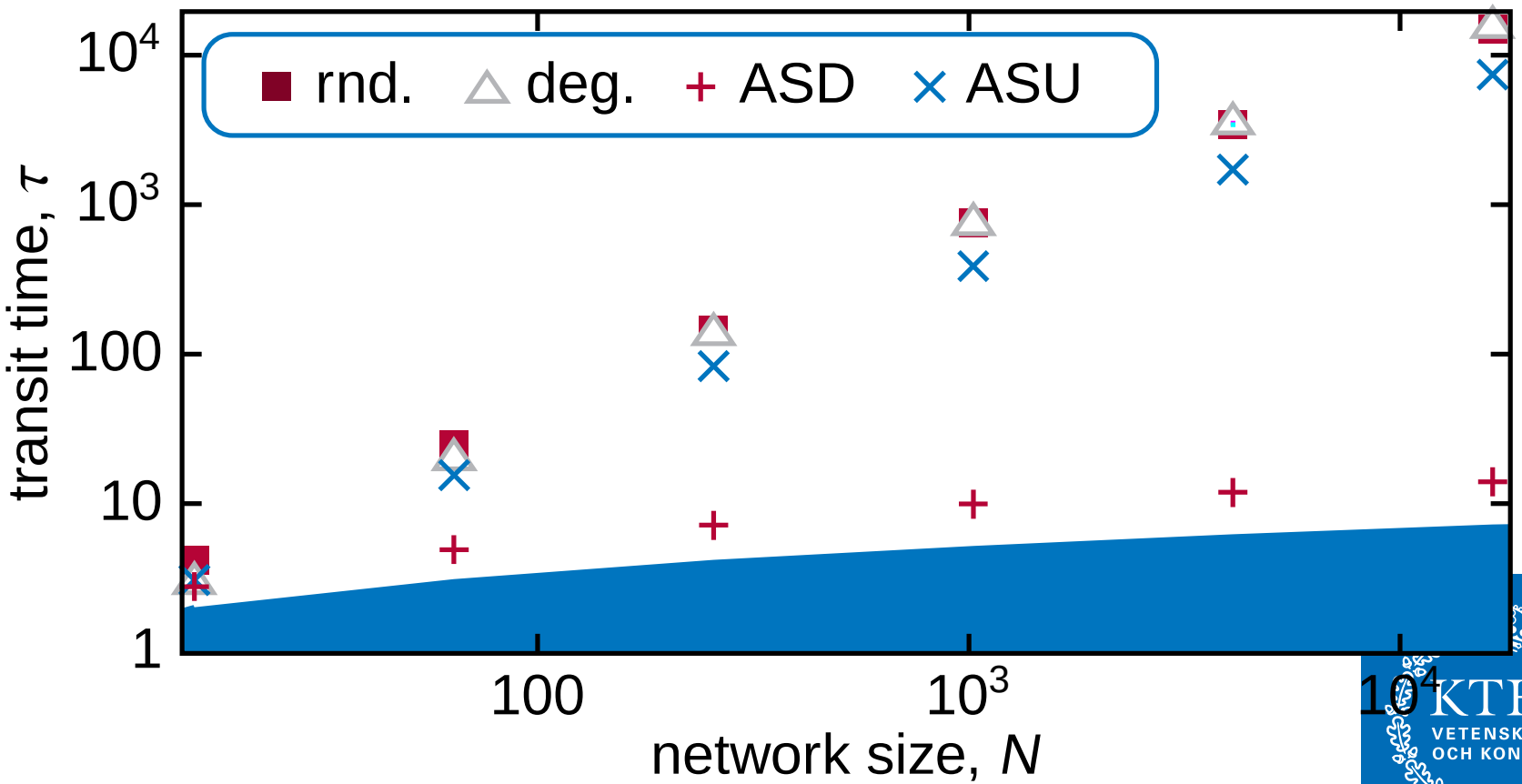
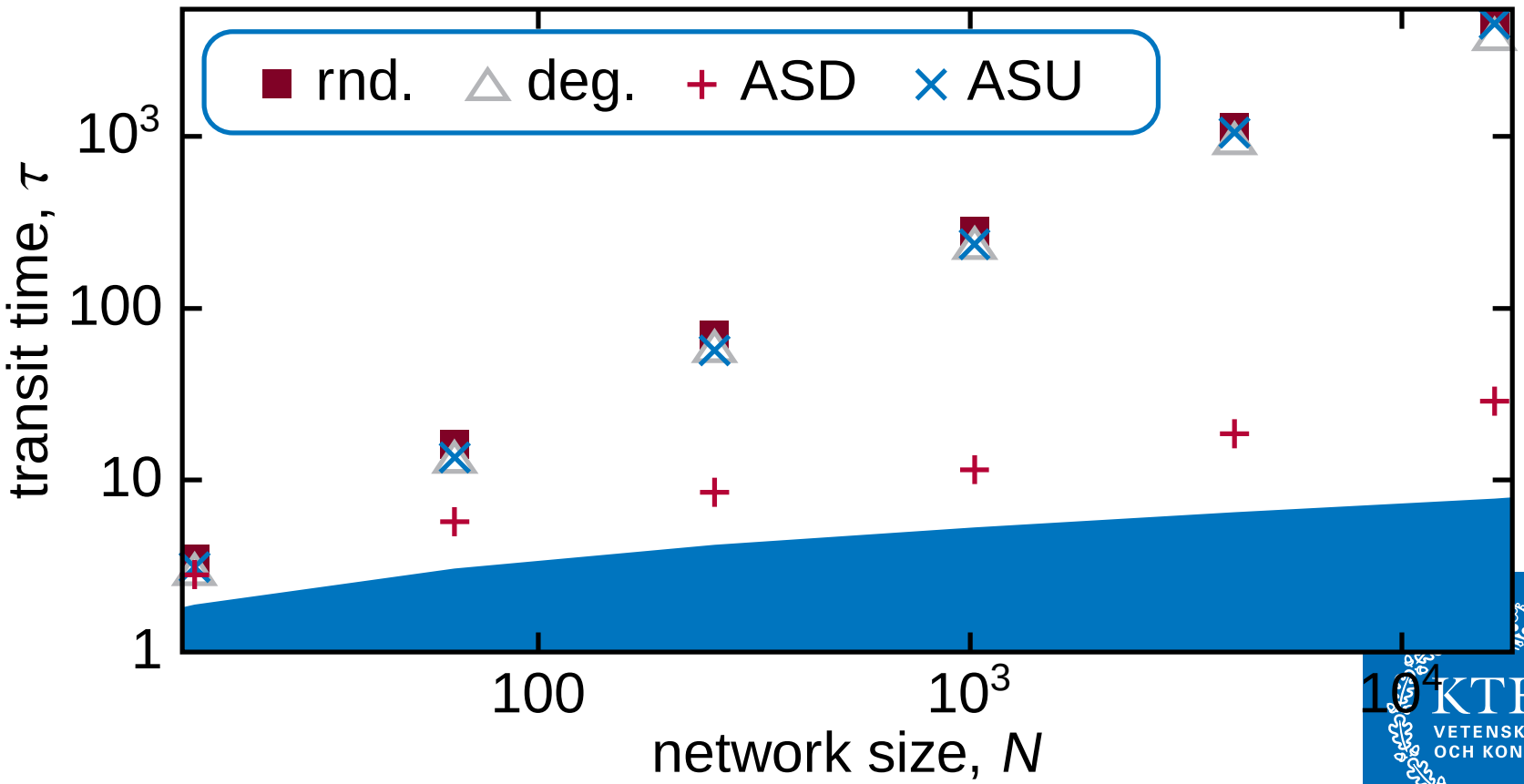
Barabási–Albert model



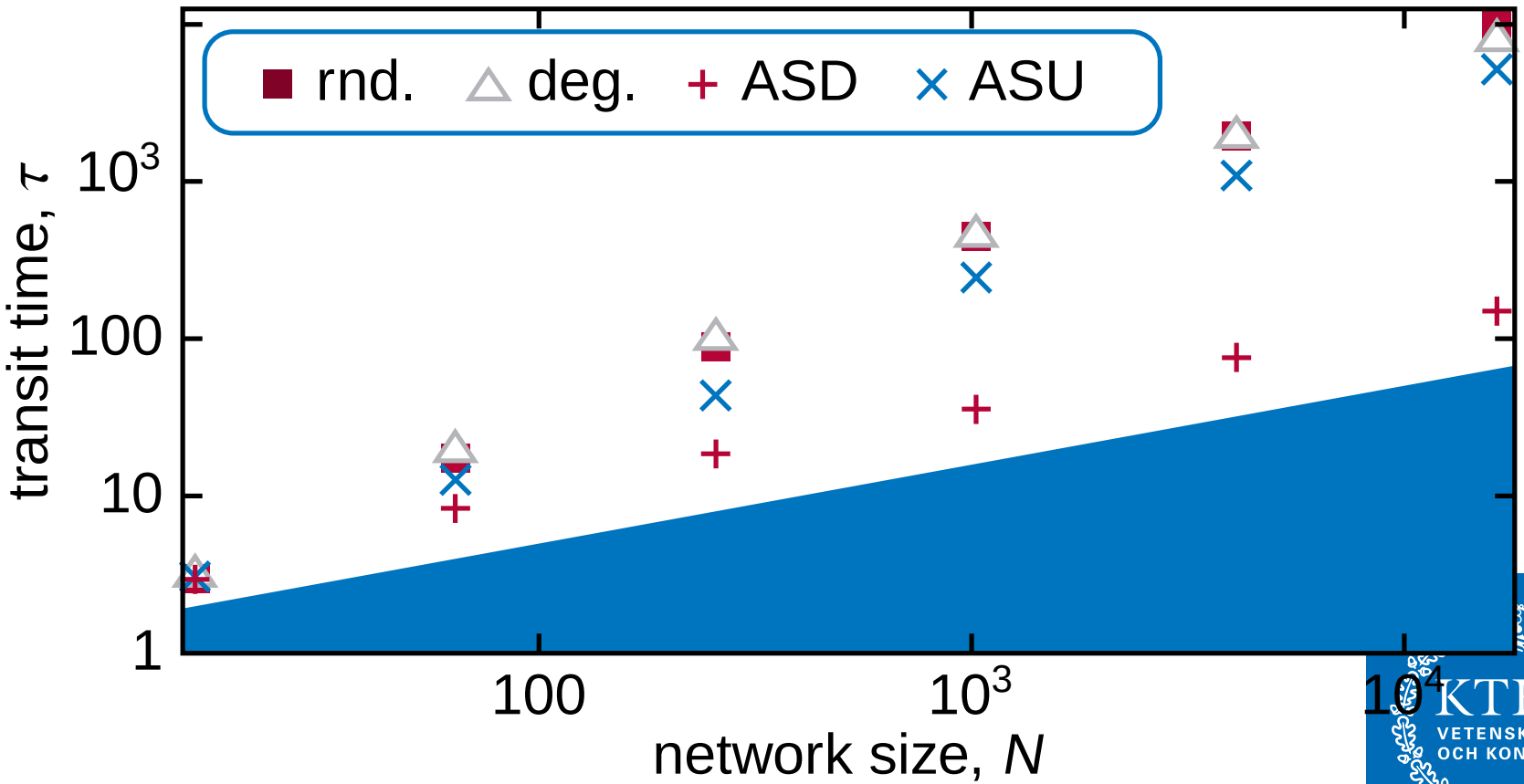
Holme–Kim model



Erdős–Rényi model



square grid


rnd.
deg.
ASD
ASU
transit time, τ
10^3
100
10
1
100
10^3
10^4
network size, N

P2P

Possible application: P2P protocols.

Things needed to be addressed:

- how to update the indices
- the root is vulnerable
- . . . and a bottleneck

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- we have presented two indexing & navigation schemes (+ two reference schemes) for the indexed-graph-navigation problem on networks
- these schemes were tested on four types of model network
- one of the schemes, ASD, performed consistently better than the others
- the other search-tree based scheme does not perform significantly better than the reference schemes

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summary

- we have presented two indexing & navigation schemes (+ two reference schemes) for the indexed-graph-navigation problem on networks
- these schemes were tested on four types of model network
- one of the schemes, ASD, performed consistently better than the others
- the other search-tree based scheme does not perform significantly better than the reference schemes

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