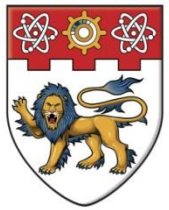


NANYANG TECHNOLOGICAL UNIVERSITY

Artificial Intelligence

Search

Lu Shijian

Assoc Prof, SCSE

Shijian.Lu@ntu.edu.sg
N4-02C-101

Overview

1. Search	Week 3
2. CSP Game Playing	Week 5
3. MDP and RL	Week 8
4. Fuzzy Rule Inference	TBA
5. Logical Reasoning	TBA
6. First-Order Logic	TBA

Problem01

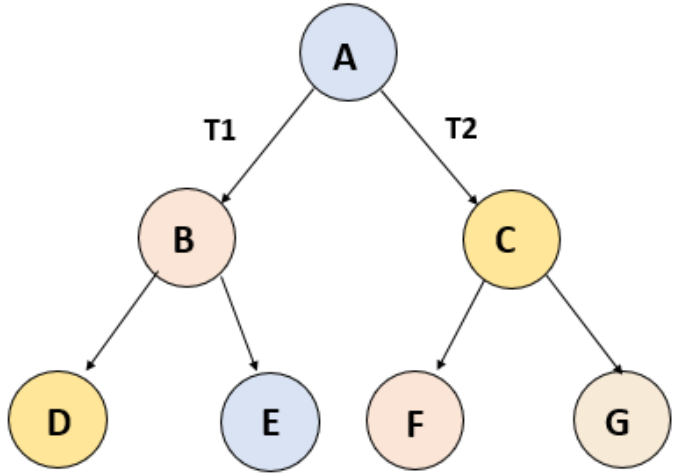
Explain which *search algorithm* is most appropriate in the following situations:

a) We have a very large search space with a large branching factor and with possibly infinite paths. We have no heuristic function. We want to find a path to the goal with minimum number of states.

b) We have a state space with lots of cycles and links of varying costs. We have no heuristic function. We want to find the shortest path.

c) Our search space is a tree of fixed depth and all the goals are at the bottom of the tree. We have a heuristic function and we want to find any goal as quickly as possible.

Problem01



Criterion	Breadth-first	Uniform-Cost	Depth-First	Depth-Limited	Iterative Deepening
Time	b^d	b^d	b^m	b^l	b^d
Space	b^d	b^d	bm	bl	bd
Optimal	Yes	Yes	No	No	Yes
Complete	Yes	Yes	No	Yes, if $l \geq d$	Yes

Problem01

a) We have a very large search space with a large branching factor and with possibly infinite paths. We have no heuristic function. We want to find a path to the goal with minimum number of states.

“very large search space”: DFS, IDS, or A* - not BFS, UCS

“large branching factor” : DFS or IDS

“possibly infinite paths” : not DFS

“no heuristic function” : not Greedy search, A* et al

“minimum number of states” : optimal, so BFS, UCS, or IDS

→ **Iterative Deepening Search (IDS)**

Problem01

b) We have a state space with lots of cycles and links of varying costs. We have no heuristic function. We want to find the shortest path.

“lots of cycles”: not DFS

“varying costs”: UCS or A* - not BFS, DFS

“no heuristic function”: not A*, Greedy search, et al

“shortest path”: optimal, so UCS or A*

→ **Uniform Cost Search**

Problem01

c) Our search space is a tree of fixed depth and all the goals are at the bottom of the tree. We have a heuristic function and we want to find any goal as quickly as possible.

“fixed depth tree”: DFS, others

“goals at the bottom”: DFS - not BFS or IDS

“heuristic function”: Greedy Best First, not DFS

“find any goal quickly” : not opt., DFS or greedy Best First

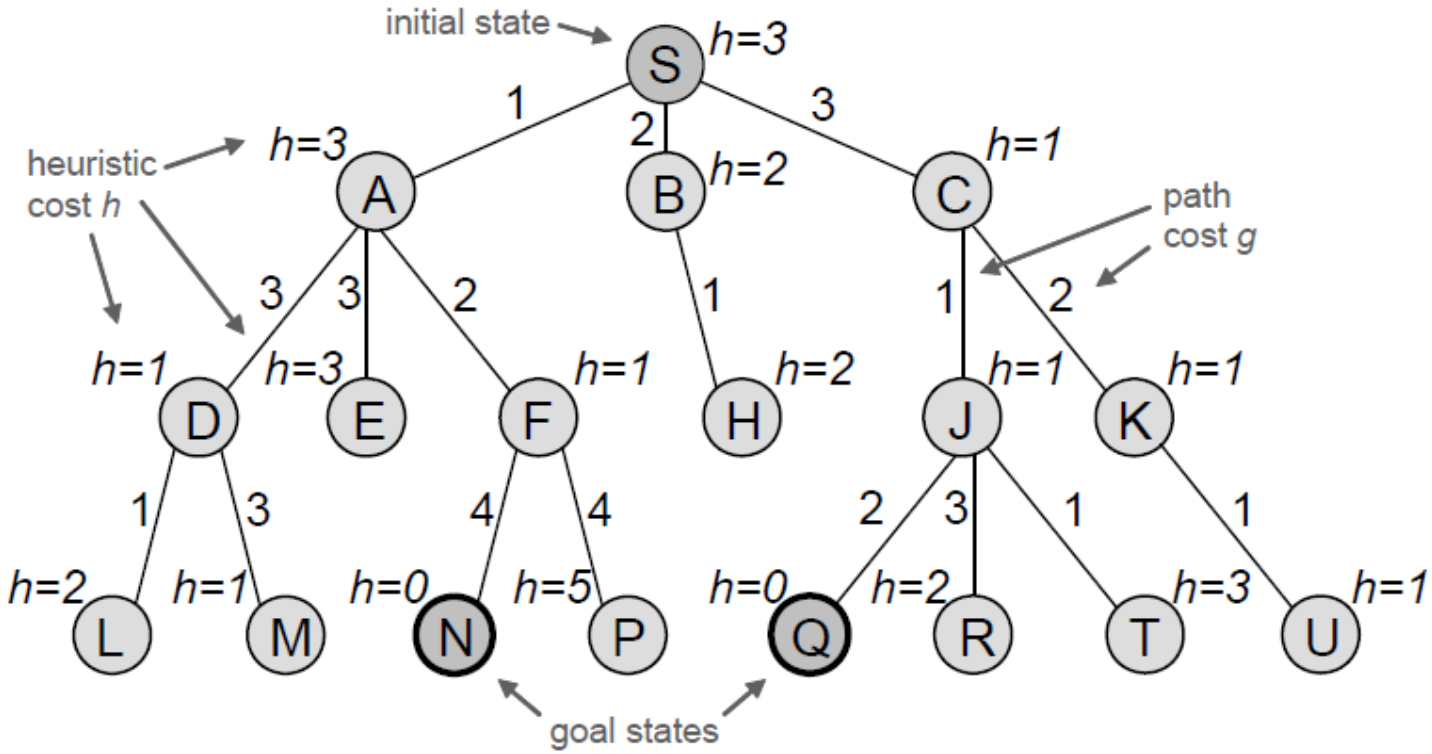
→ **Greedy Best First Search**

Problem02

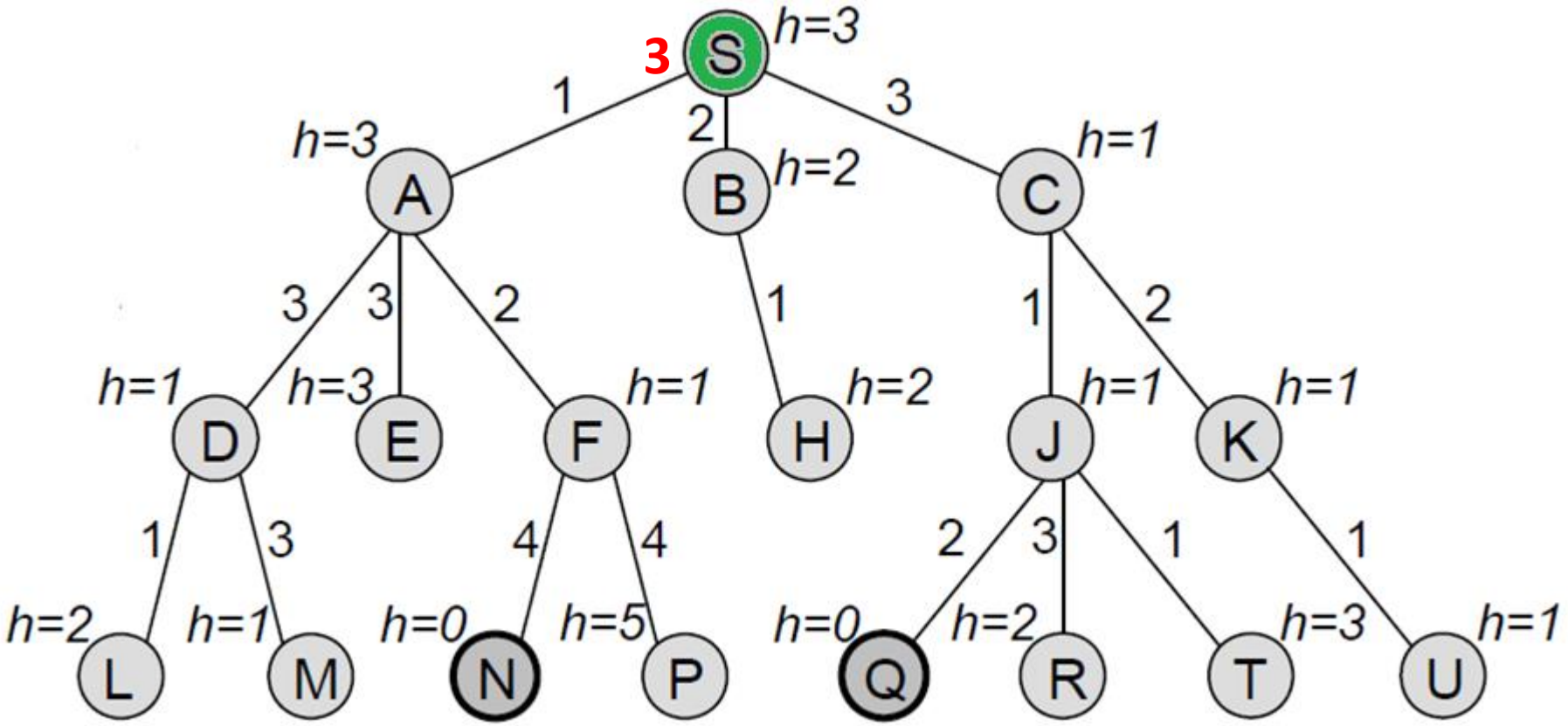
Consider the search problem defined by the annotated search tree below.

a) Apply the standard *A* search algorithm.* Draw all generated nodes, write their f-costs, and number expanded nodes in order of expansion. Assume that the children of a node are processed in alphabetical order, and that nodes of equal priority are extracted from the search queue in FIFO order.

b) State how many nodes were generated and how many were expanded. Comment on the solution obtained and the *effectiveness* of the search. What do you think of the *heuristic function h* employed?



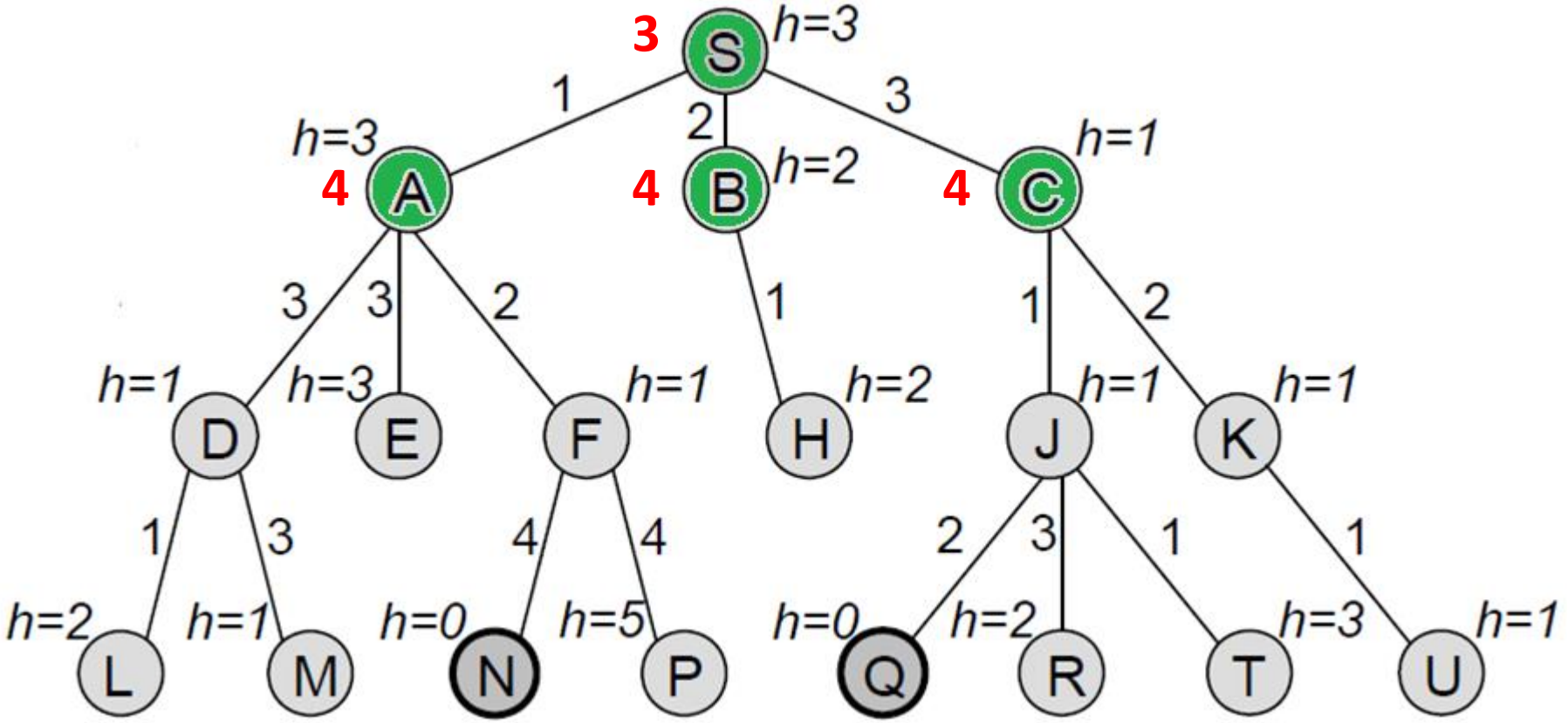
Problem02



1. $f(S) = g(S) + h(S)$
$= 0 + 3 = 3$

S

Problem02



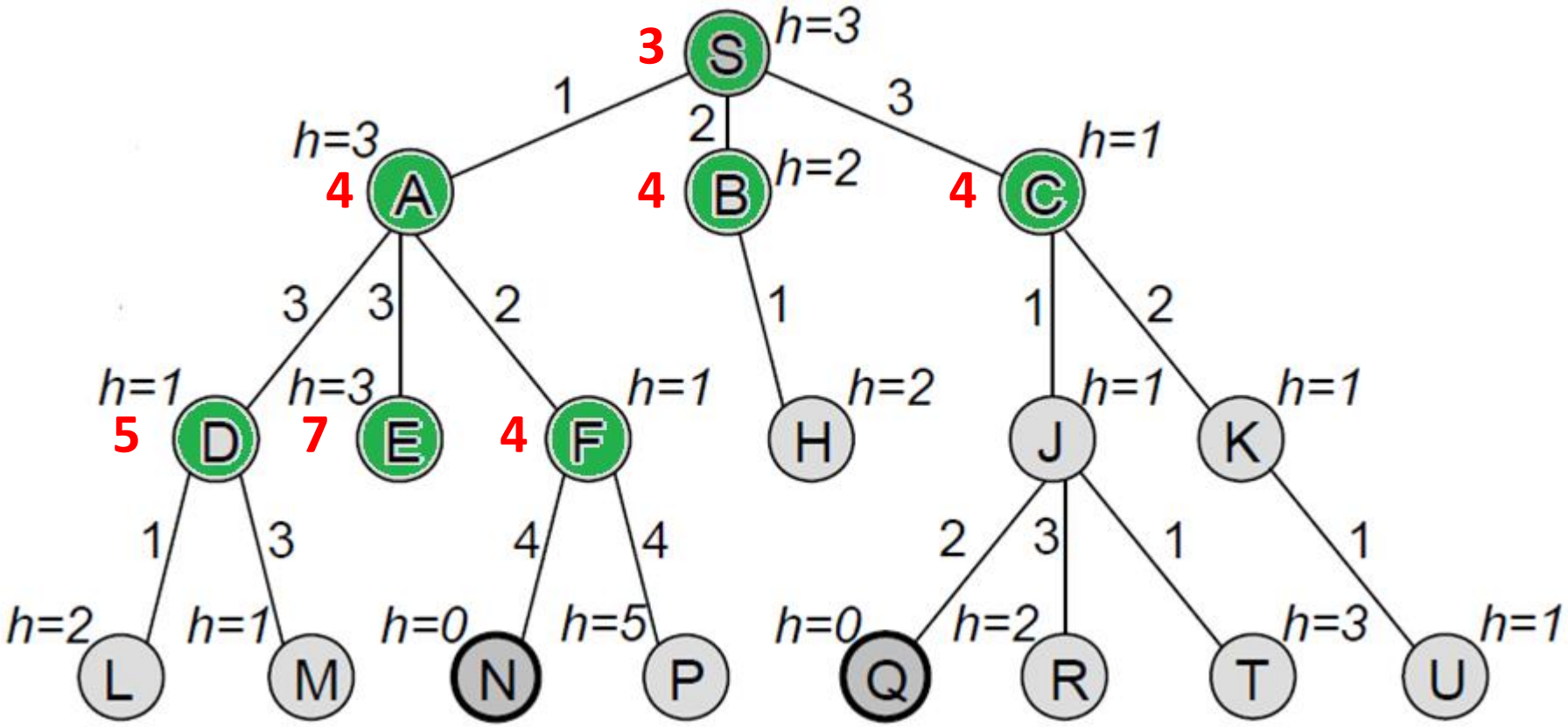
2. $f(A) = g(A) + h(A)$
$= 1 + 3 = 4$

$f(B) = g(B) + h(B)$
$= 2 + 2 = 4$

$f(C) = g(C) + h(C)$
$= 1 + 3 = 4$

A, B, C

Problem02



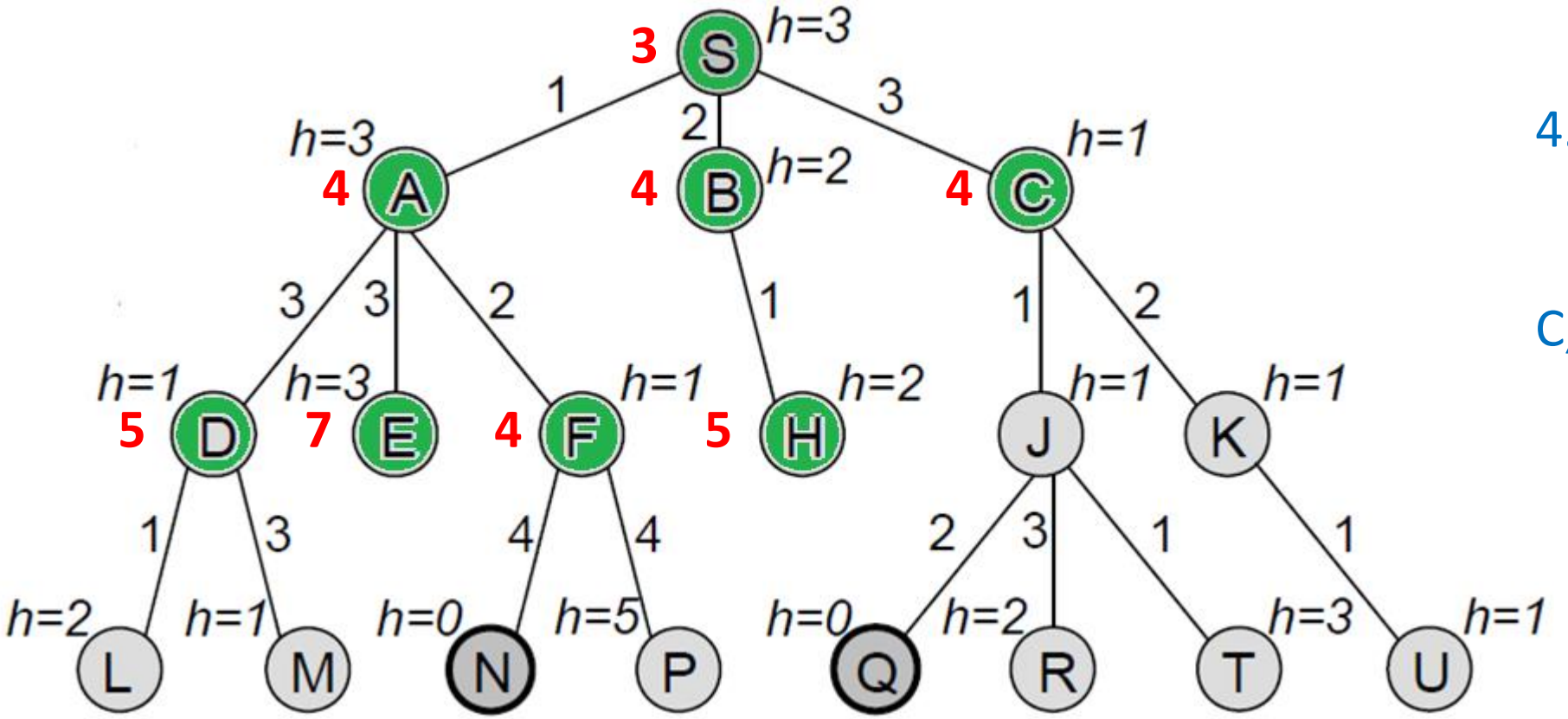
3. $f(D) = g(D) + h(D)$
$= 1 + 3 + 1 = 5$

$f(E) = g(E) + h(E)$
$= 1 + 3 + 3 = 7$

$f(F) = g(F) + h(F)$
$= 1 + 2 + 1 = 4$

B, C, F, D, E

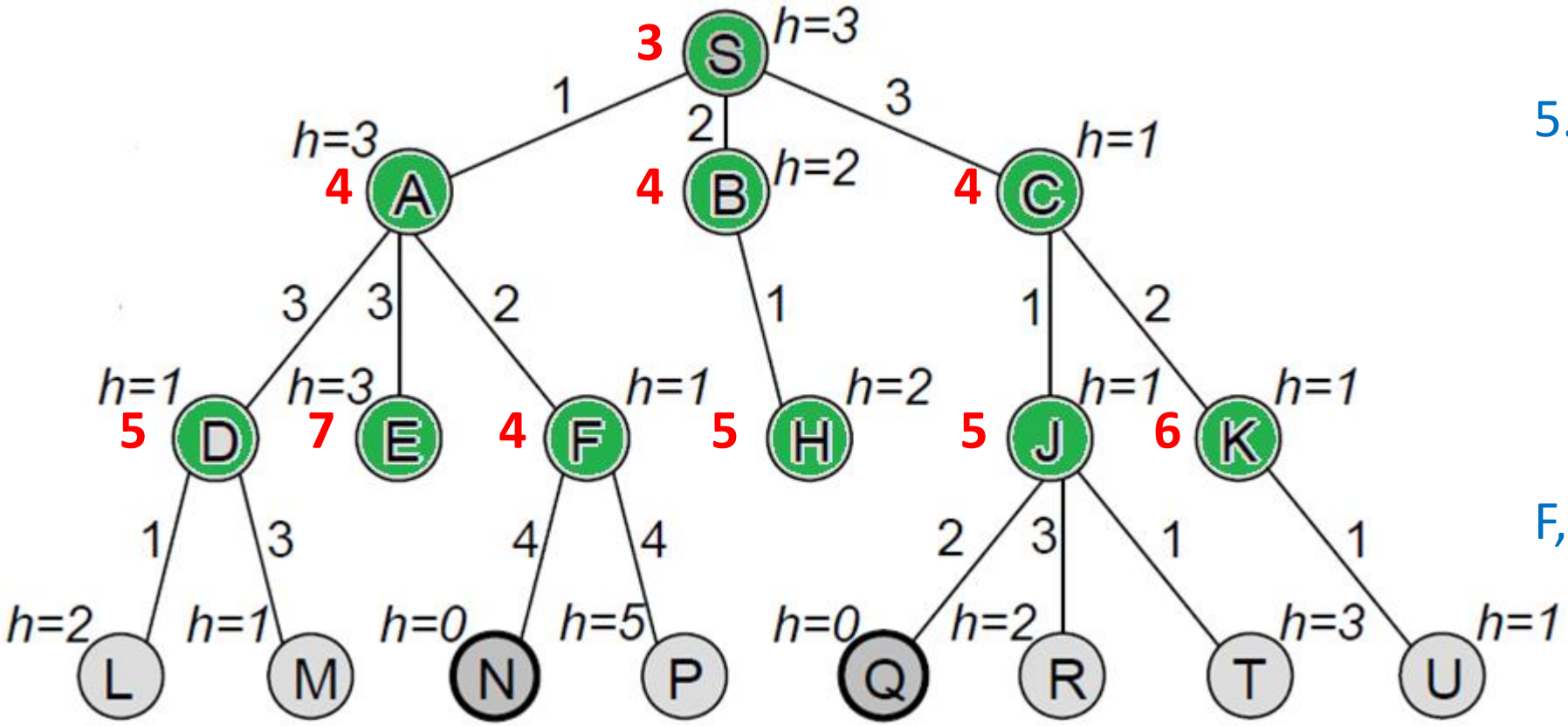
Problem02



4. $f(H) = g(H) + h(H)$
$= 2 + 1 + 2 = 5$

C, F, D, H, E

Problem02

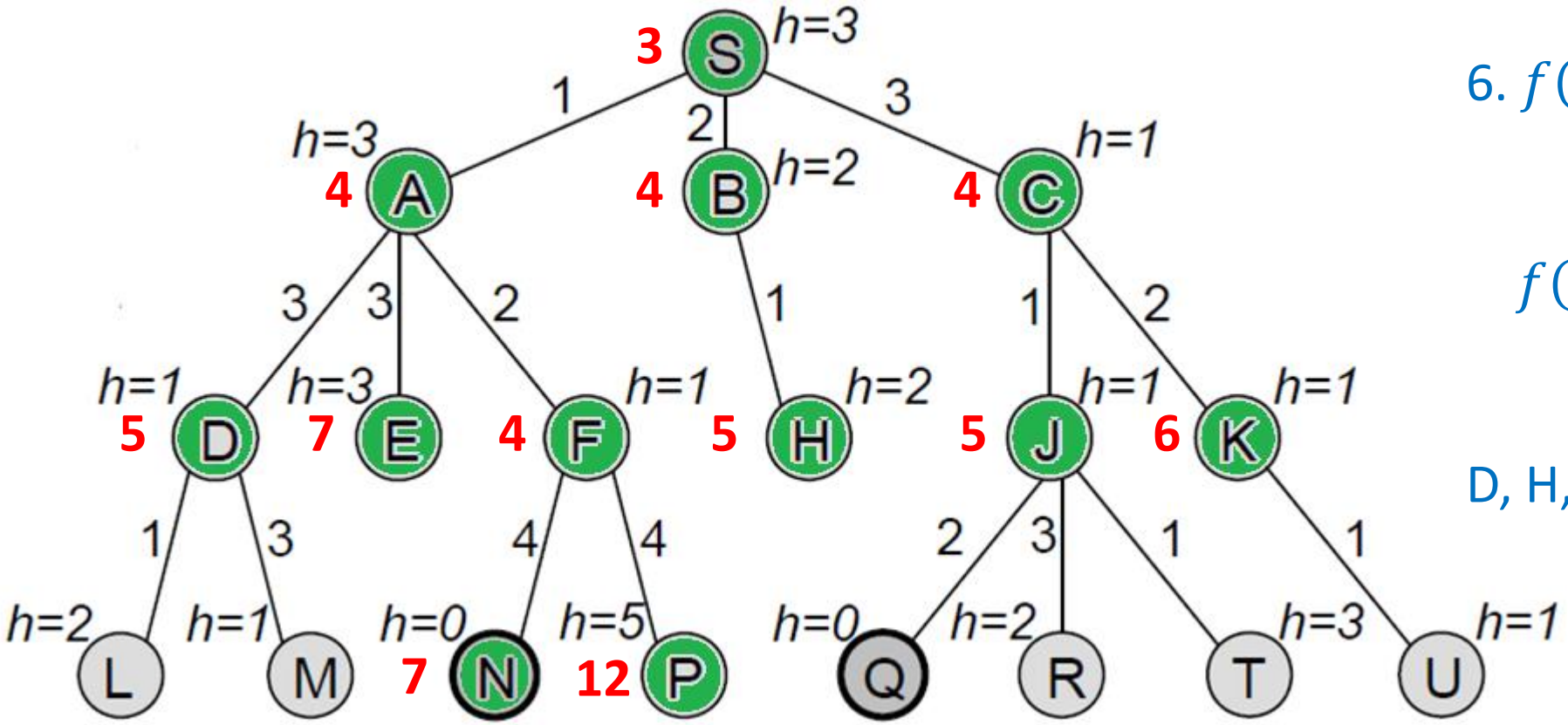


5. $f(J) = g(J) + h(J)$
$= 3 + 1 + 1 = 5$

$f(K) = g(K) + h(K)$
$= 3 + 2 + 1 = 6$

F, D, H, J, K, E

Problem02

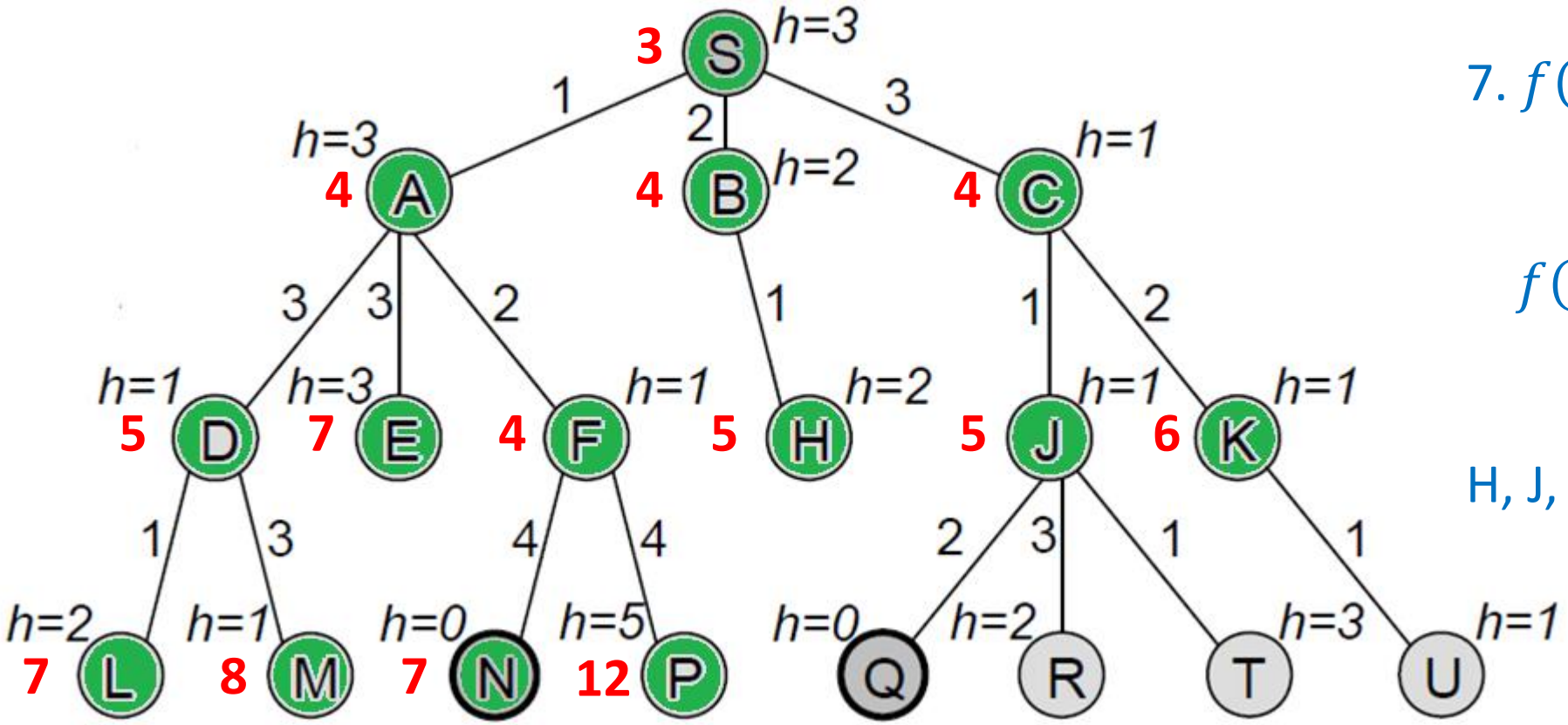


6. $f(N) = g(N) + h(N)$
$= 1 + 2 + 4 + 0 = 7$

$f(P) = g(P) + h(P)$
$= 1 + 2 + 4 + 5 = 12$

D, H, J, K, E, N, P

Problem02

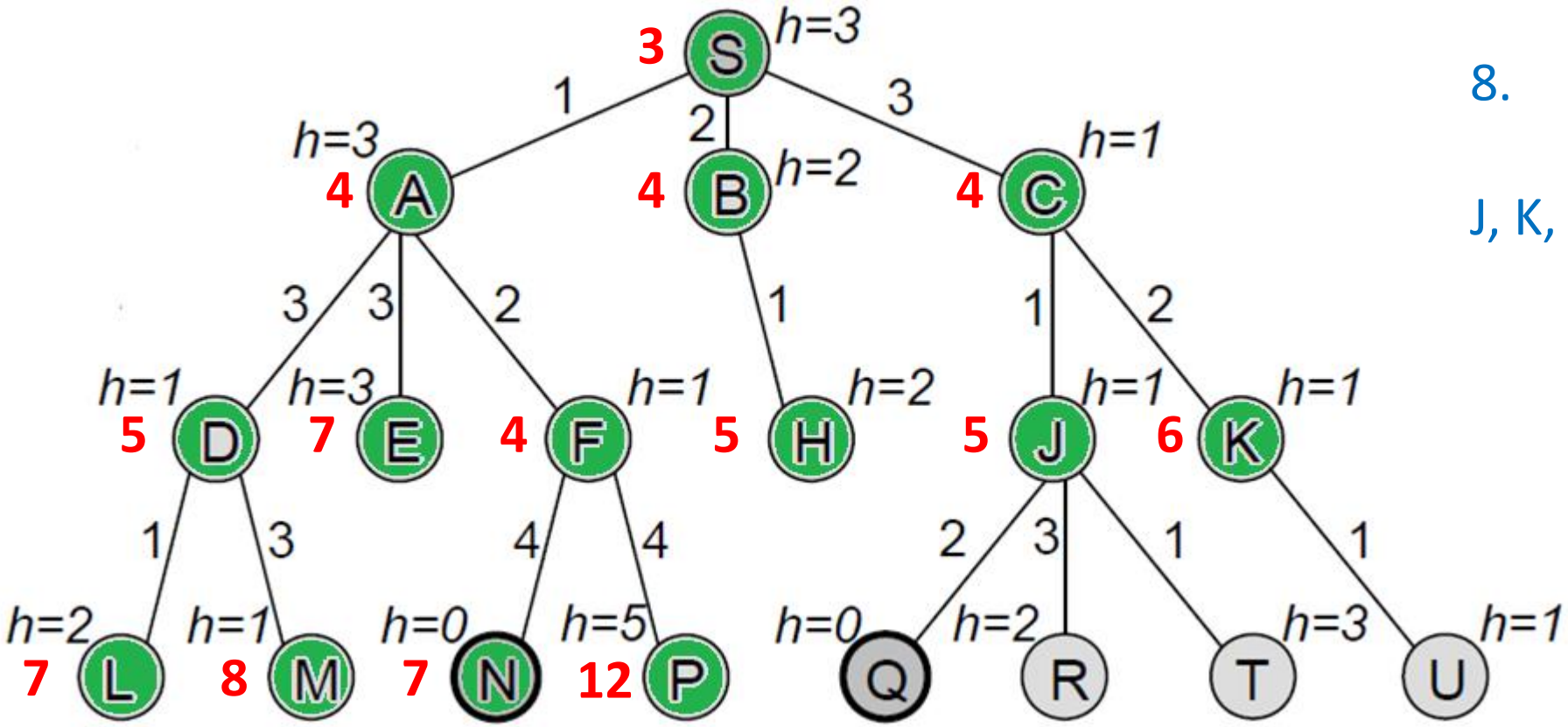


7. $f(L) = g(L) + h(L)$
$= 1 + 3 + 1 + 2 = 7$

$f(M) = g(M) + h(M)$
$= 1 + 3 + 3 + 1 = 8$

H, J, K, E, L, N, M, P

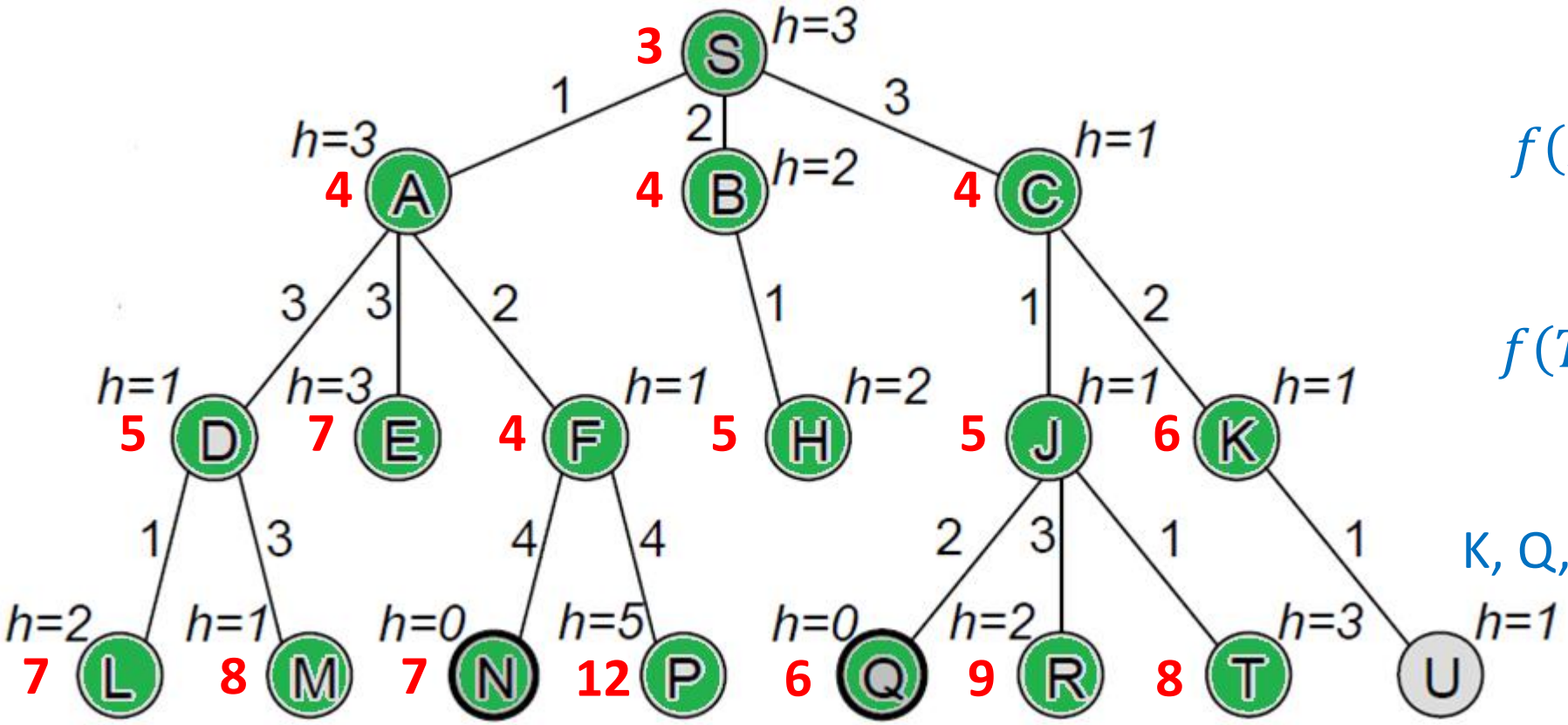
Problem02



8.

J, K, E, L, N, M, P

Problem02



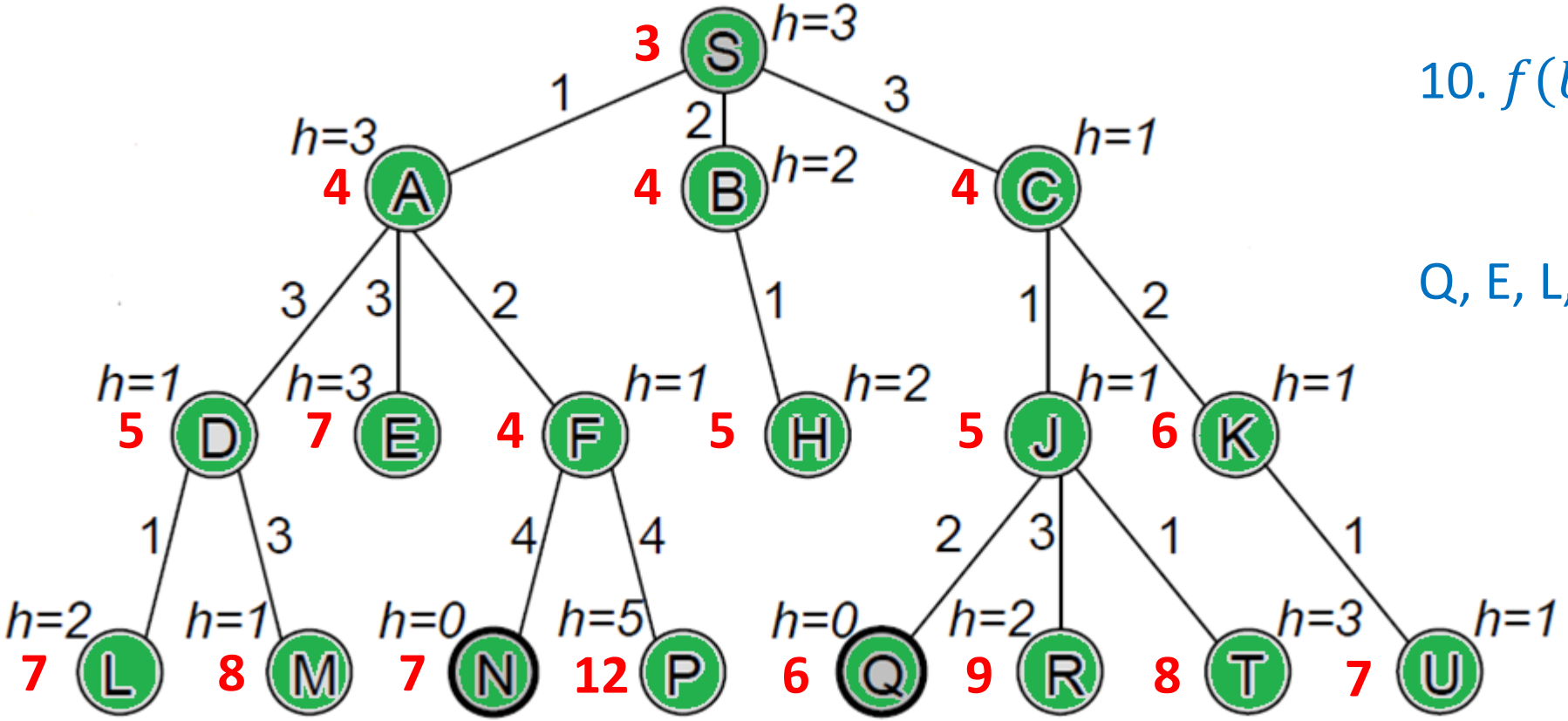
9. $f(Q) = g(Q) + h(Q)$
$= 3 + 1 + 2 + 0 = 6$

$f(R) = g(R) + h(R)$
$= 3 + 1 + 3 + 2 = 9$

$f(T) = g(T) + h(T)$
$= 3 + 1 + 1 + 3 = 8$

K, Q, E, L, N, M, T, R, P

Problem02



10. $f(U) = g(U) + h(U)$
$= 3 + 2 + 1 + 1 = 7$

Q, E, L, N, U, M, T, R, P

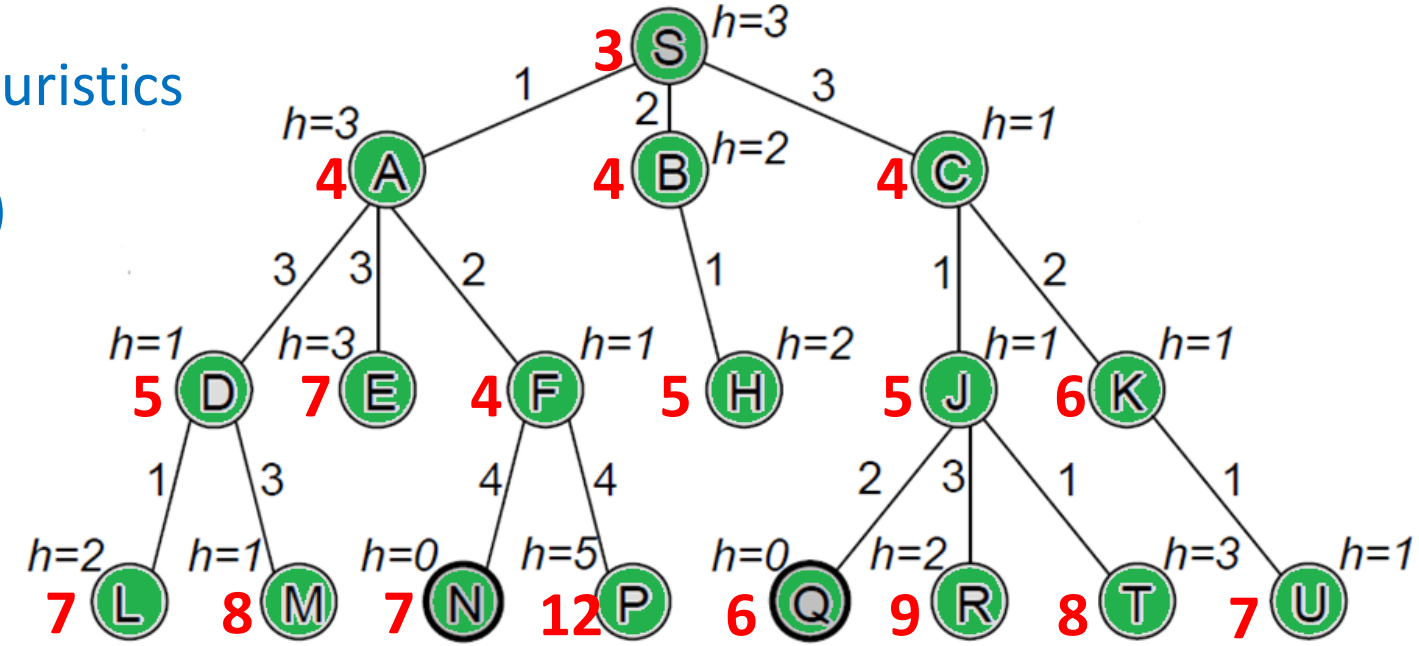
Problem02

2.(b). State how many nodes were generated and how many were expanded. Comment on the solution obtained and the effectiveness of the search. What do you think of the heuristic function h employed?

Nodes generated: 18, *nearly exhaustive search* (!)

Nodes expanded: 10, ill-guided, poor heuristics

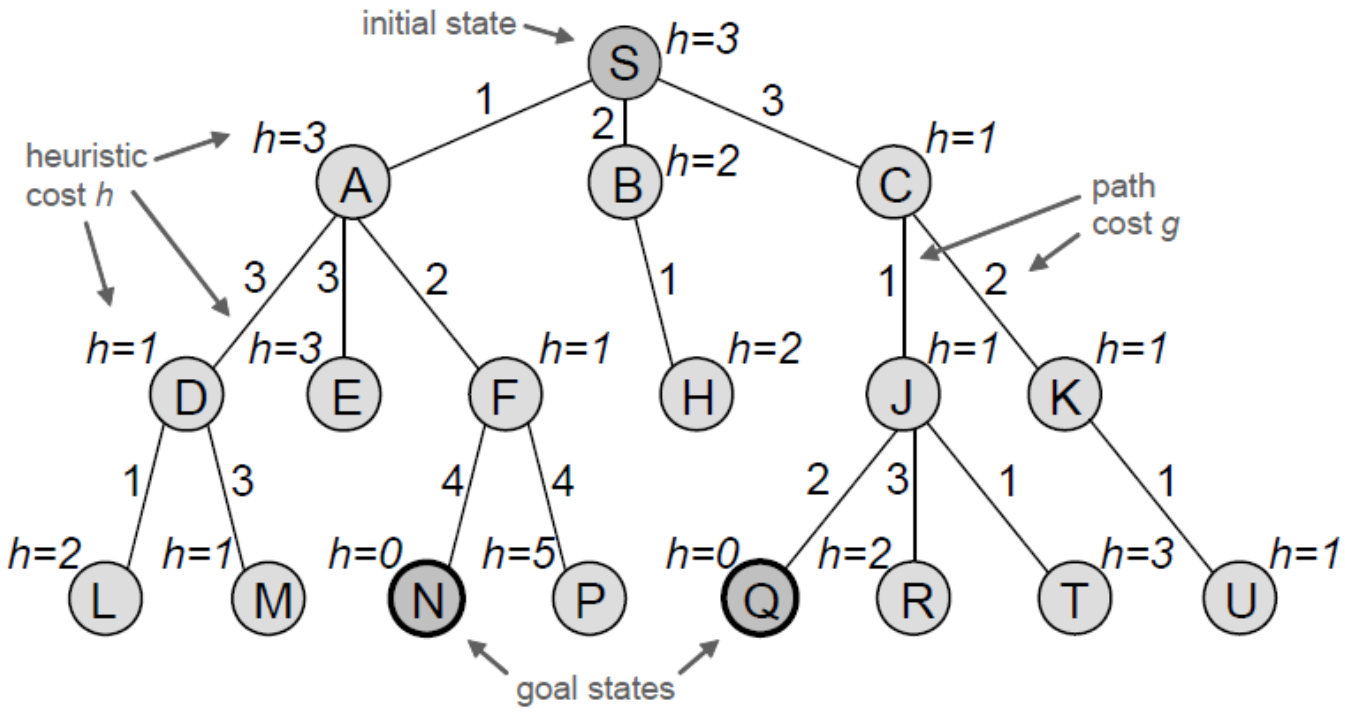
optimal solution (optimistic, misleading)



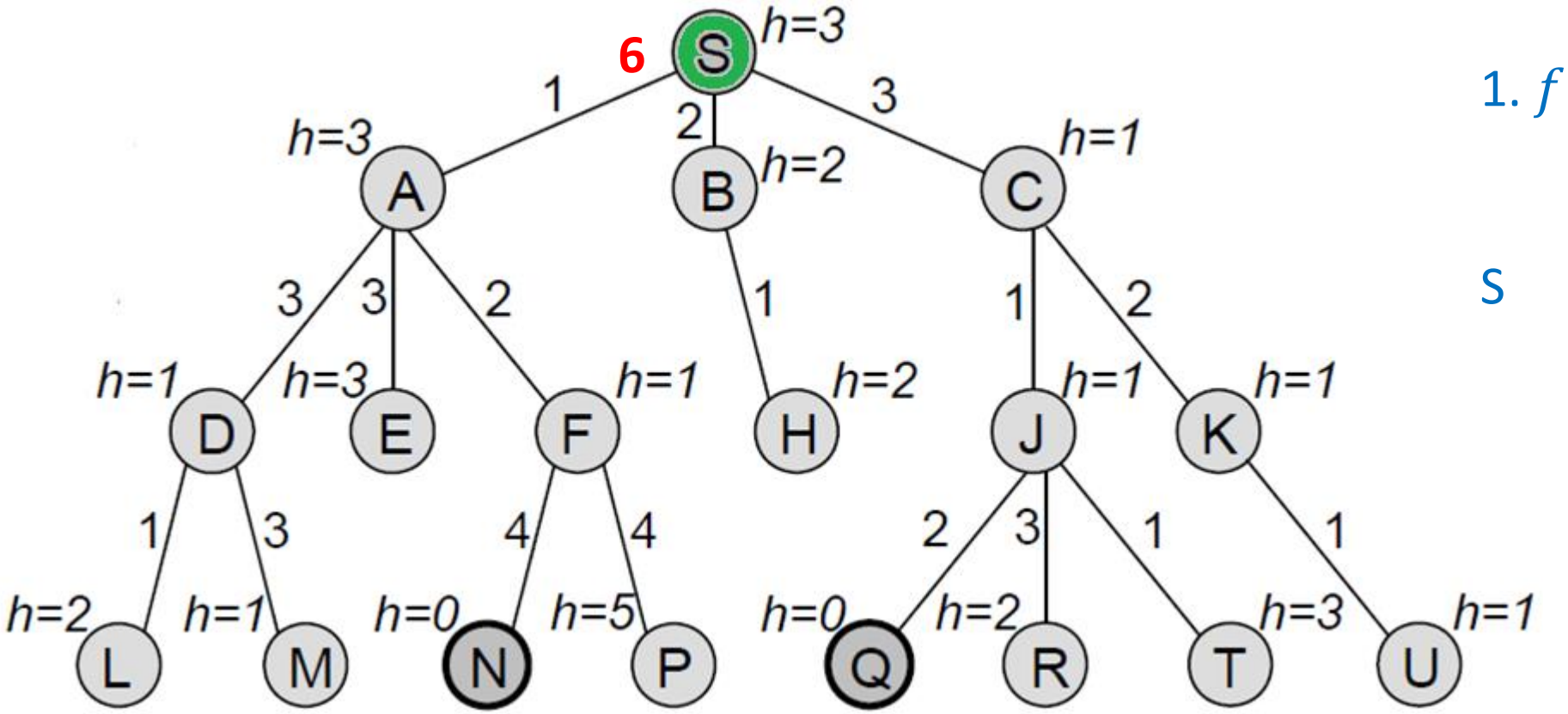
Problem03

The *w-A** search algorithm is a *weighted* variant of *A** that places more emphasis on the heuristic function by using the *f*-cost $f_w(n) = g(n) + w \times h(n)$, for any $w > 1$.

a) Similarly to question 2.2a, apply the *w-A** search algorithm for $w = 2$.
b) Similarly to question 2.2b, comment on the *performance* and usefulness of the *w-A** search algorithm – in this case and in general.



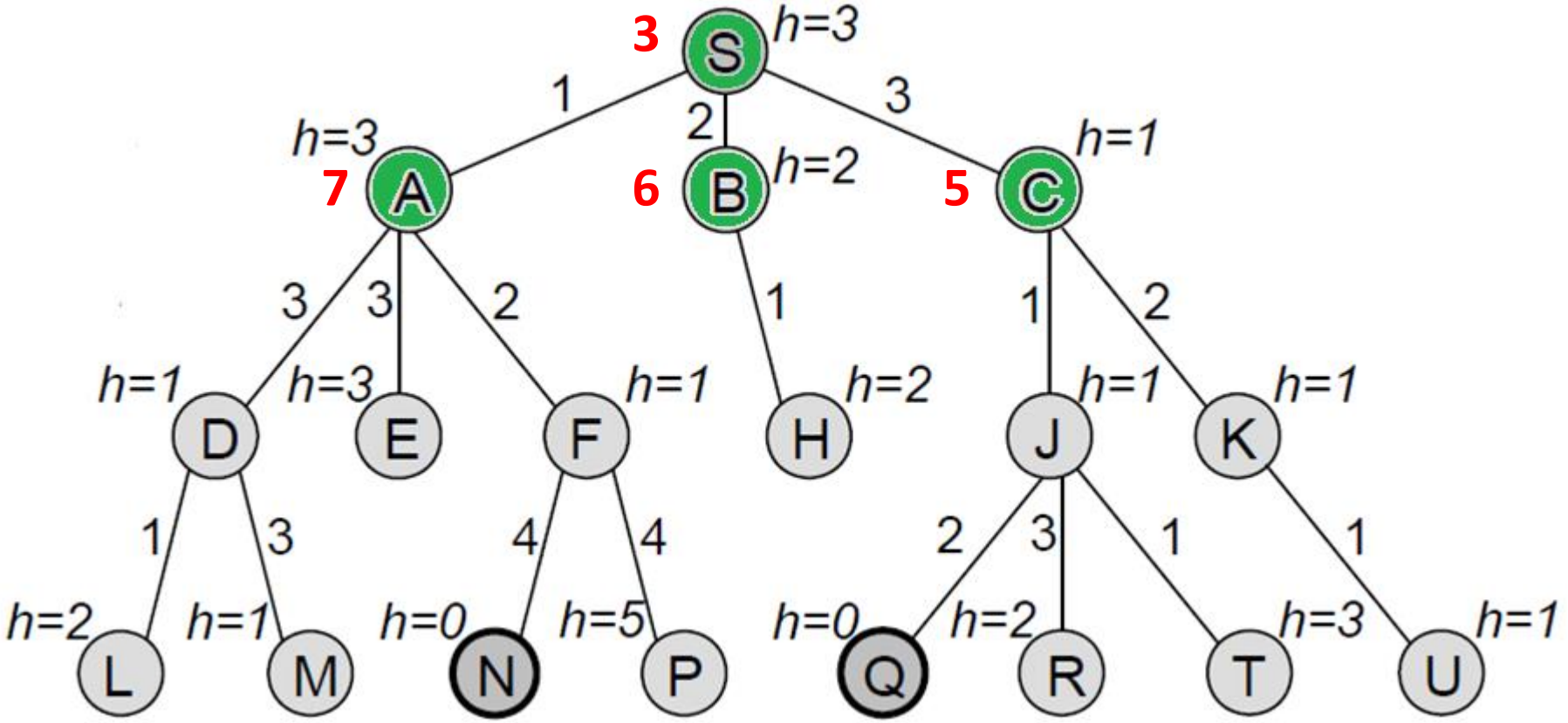
Problem03



1. $f(S) = g(S) + h(S)$
$= 0 + 2 * 3 = 6$

S

Problem03



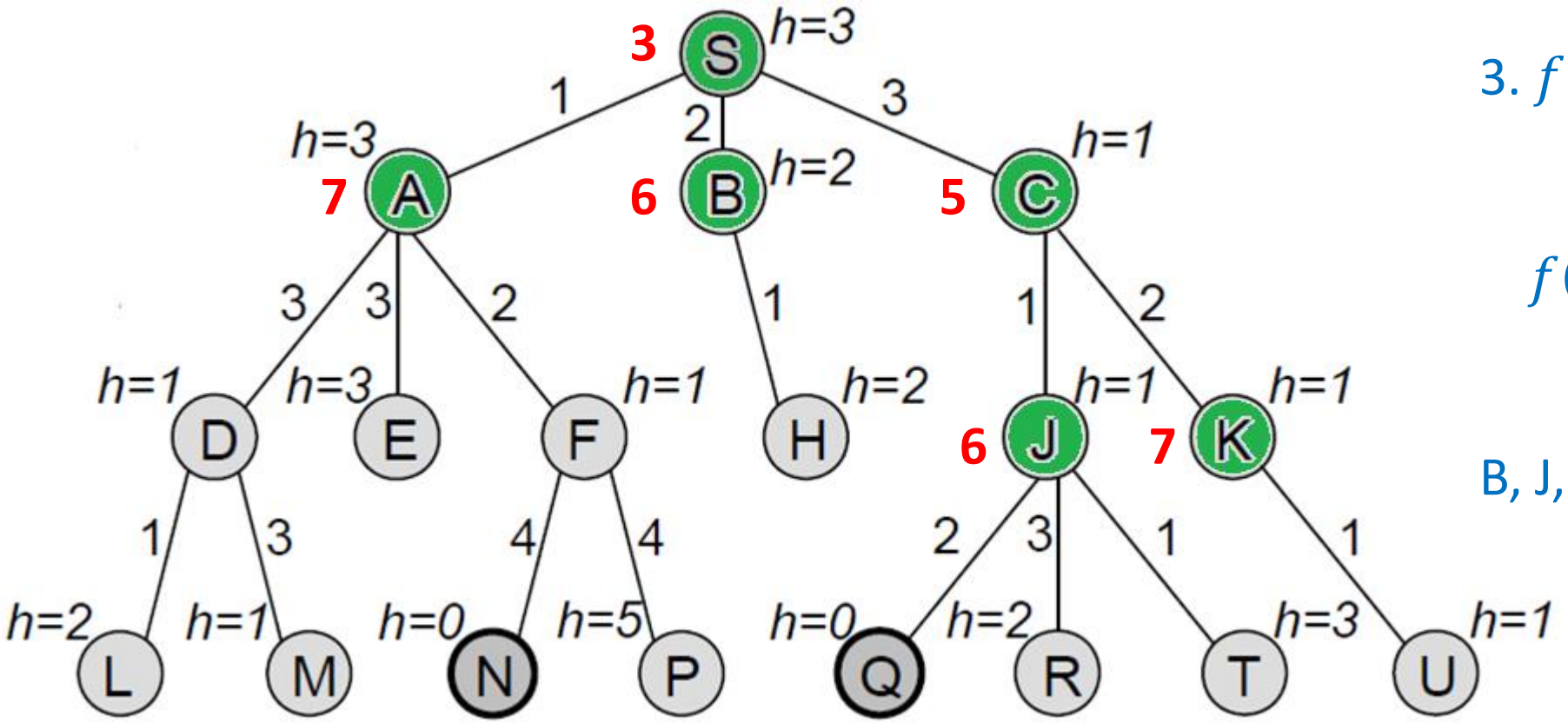
2. $f(A) = g(A) + h(A)$
$= 1 + 2 * 3 = 7$

$f(B) = g(B) + h(B)$
$= 2 + 2 * 2 = 6$

$f(C) = g(C) + h(C)$
$= 3 + 2 * 1 = 5$

C, B, A

Problem03

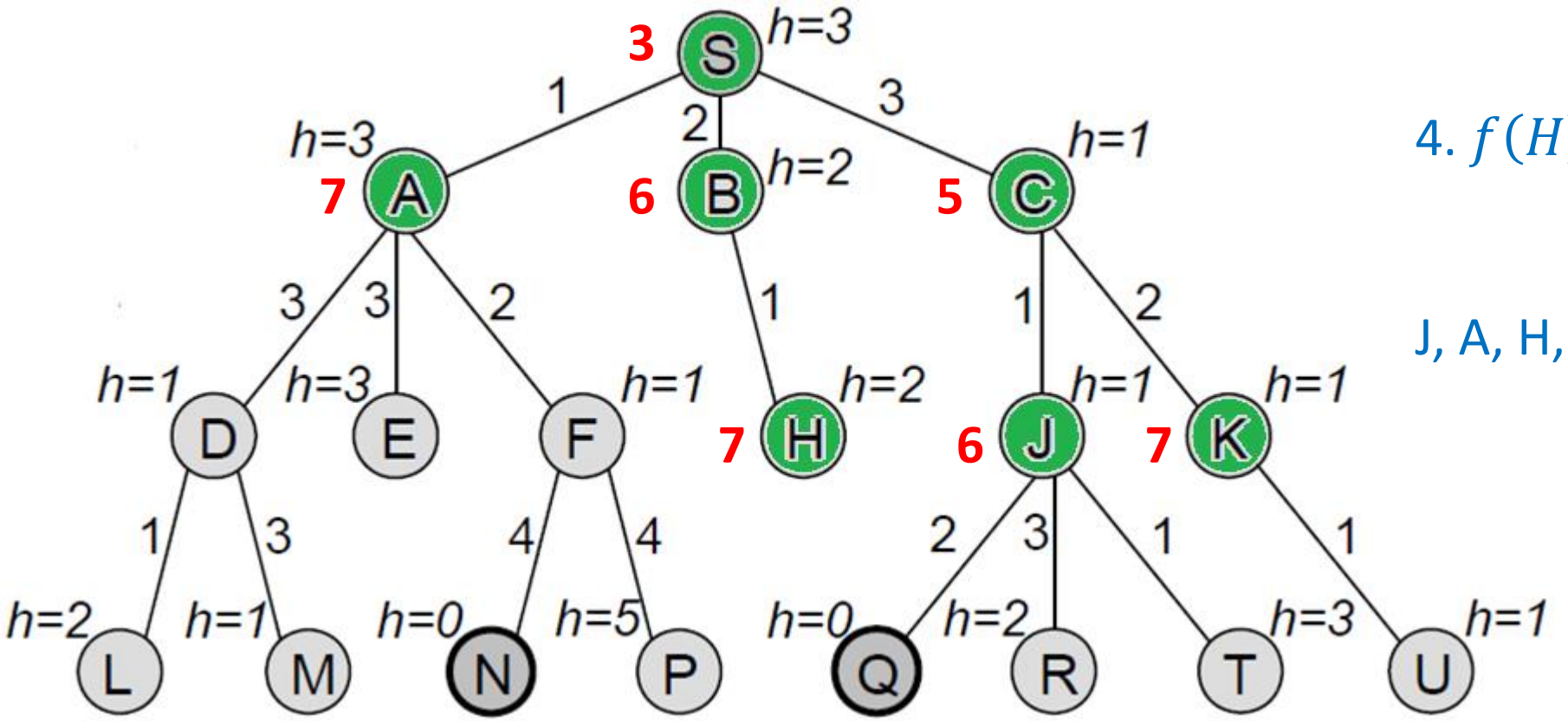


3. $f(J) = g(J) + h(J)$
$= 3 + 1 + 2 * 1 = 6$

$f(K) = g(K) + h(K)$
$= 3 + 2 + 2 * 1 = 7$

B, J, A, K

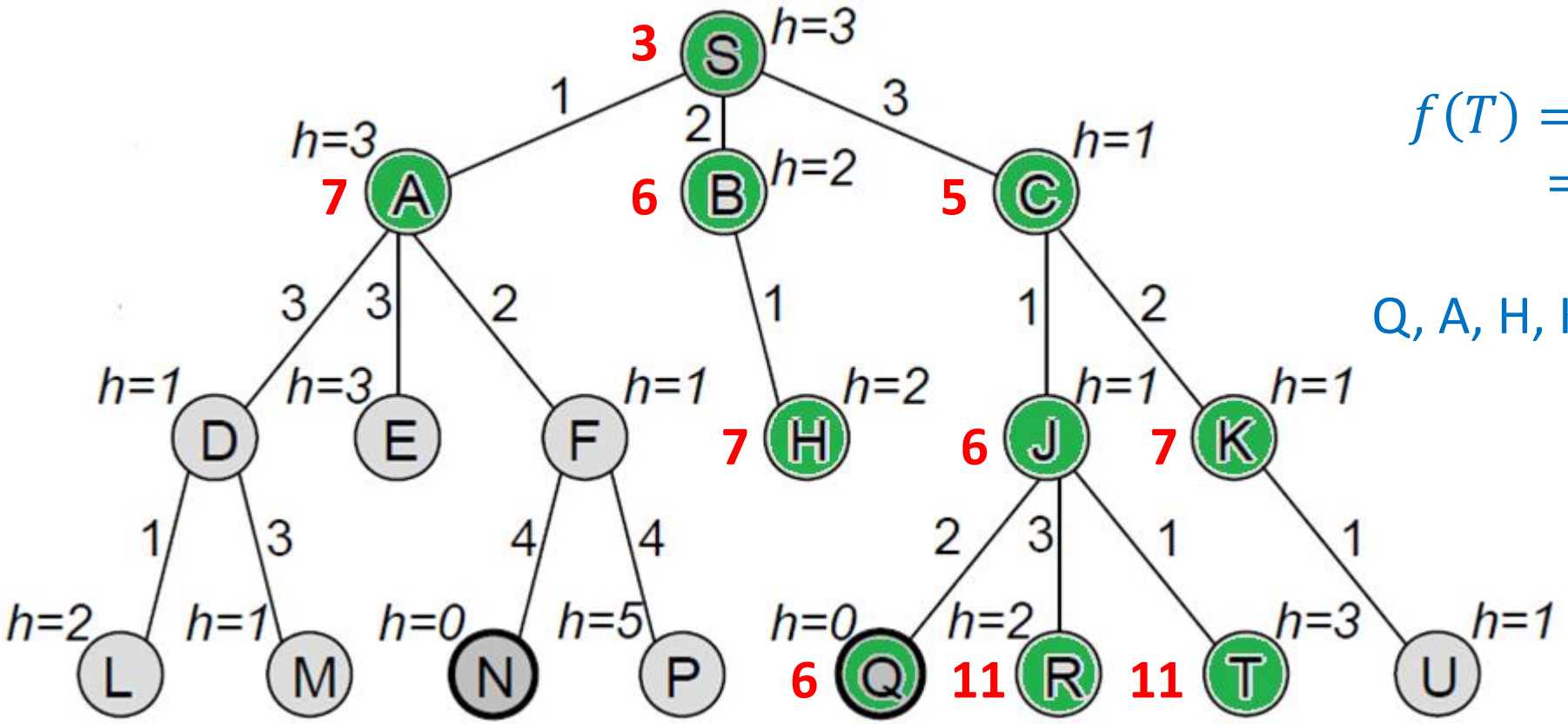
Problem03



4. $f(H) = g(H) + h(H)$
$= 2 + 1 + 2 * 2 = 7$

J, A, H, K

Problem03



5. $f(Q) = g(Q) + h(Q)$
$= 3 + 1 + 2 + 2 * 0 = 6$

$f(R) = g(R) + h(R)$
$= 3 + 1 + 3 + 2 * 2 = 11$

$f(T) = g(T) + h(T)$
$= 3 + 1 + 1 + 2 * 3 = 11$

Q, A, H, K, R, T

Problem03

3.2(b). State how many nodes were generated and how many were expanded. Comment on the solution obtained and the effectiveness of the search. What do you think of the heuristic function h employed?

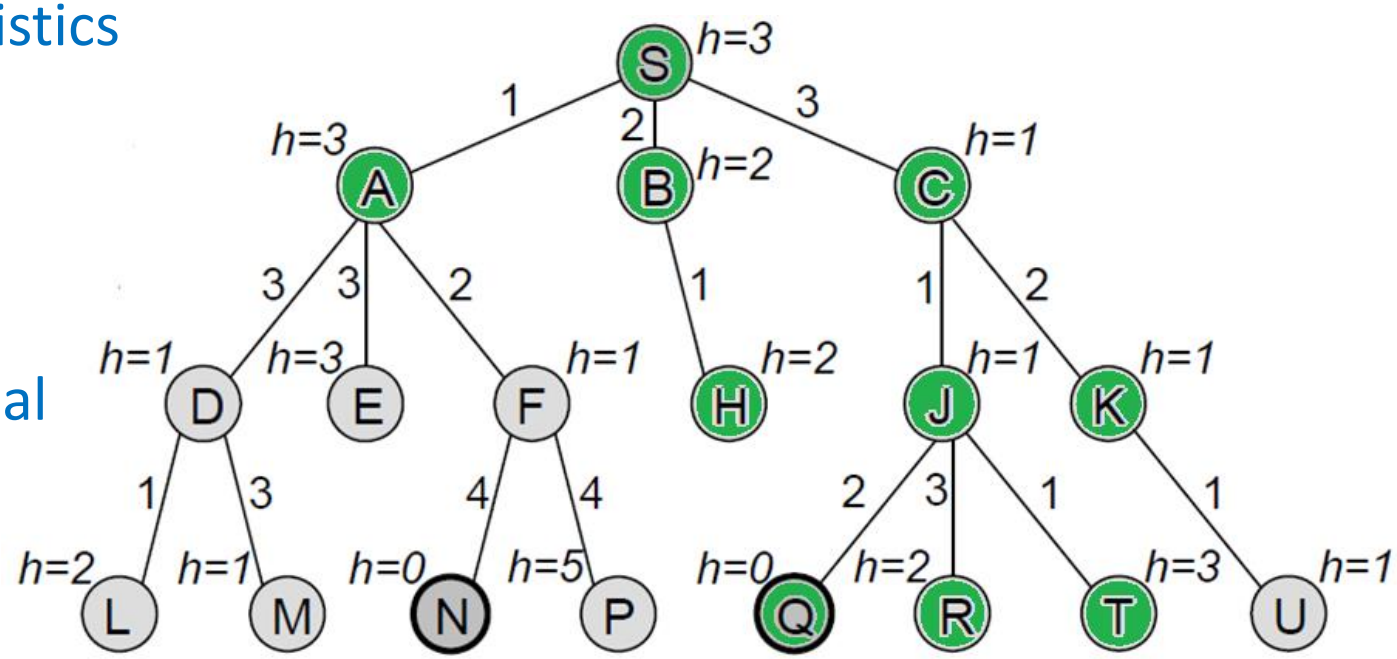
Nodes generated: 10, well-guided *search* (!)

Nodes expanded: 5, much improved heuristics

w-A* – pros: faster, complete

cons: not optimal (no guarantee)

increase w? faster yet, less and less optimal



NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

Copyright Notice

All course materials (including and not limited to lecture slides, handouts, recordings, assessments and assignments), are solely for your own educational purposes at NTU only. All course materials are protected by copyright, trademarks or other rights.

All rights, title and interest in the course materials are owned by, licensed to or controlled by the University, unless otherwise expressly stated. The course materials shall not be uploaded, reproduced, distributed, republished or transmitted in any form or by any means, in whole or in part, without written approval from the University.

You are also not allowed to take any photograph, video recording, audio recording or other means of capturing images and/or voice of any of the course materials (including and not limited to lectures, tutorials, seminars and workshops) and reproduce, distribute and/or transmit in any form or by any means, in whole or in part, without written permission from the University.

Appropriate action(s) will be taken against you (including and not limited to disciplinary proceedings and/or legal action) if you are found to have committed any of the above or infringed copyright.

1 August 2022