Line Routing Algorithms

Dr. Philip Brisk
Department of Computer Science and Engineering
University of California, Riverside

CS 220
Synthesis of Digital Systems

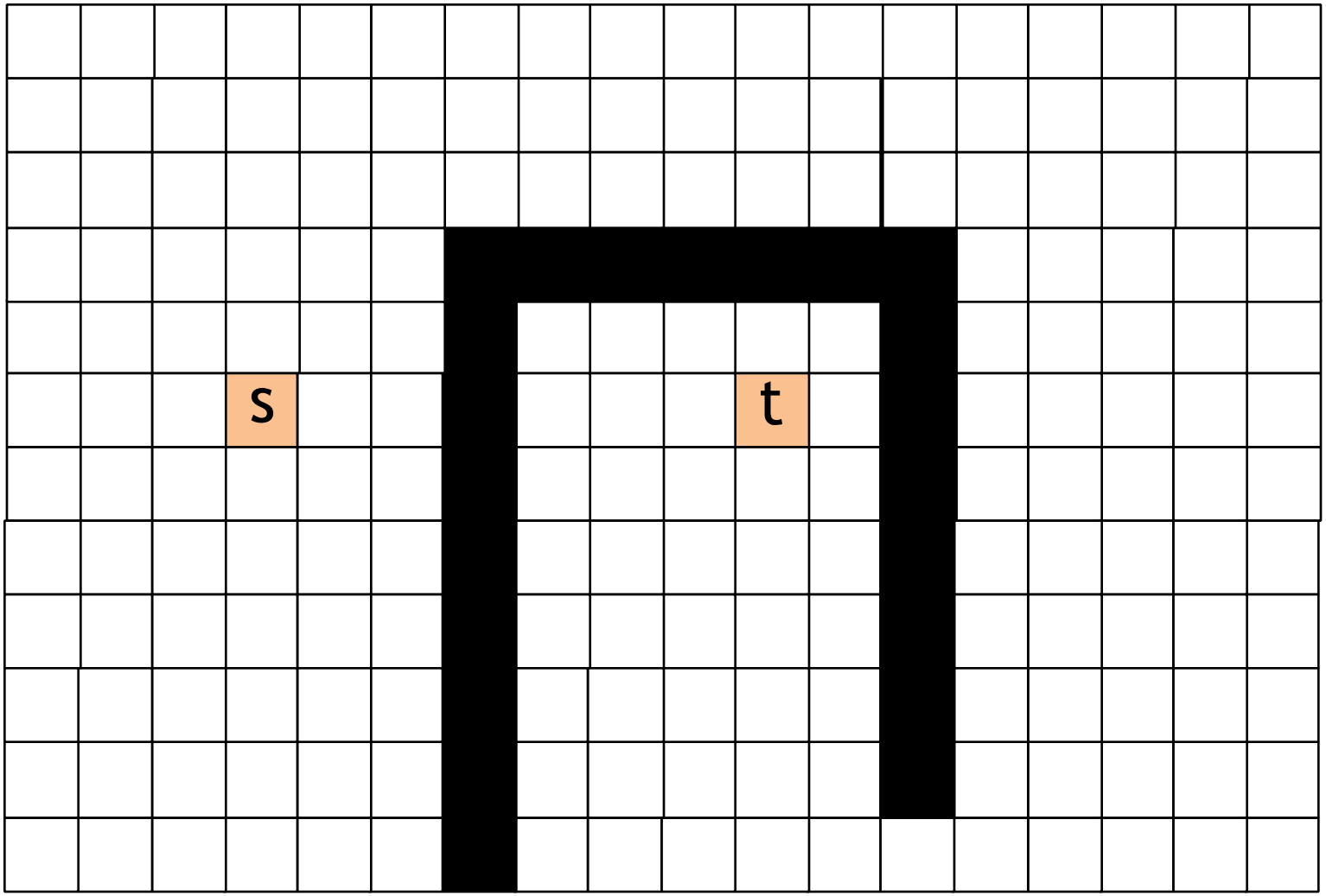
Mikami-Tabuchi Algorithm

- Mikami, K., and Tabuchi, K. (1968), *A Computer Program for Optimal Routing of Printed Circuit Connections*, Proceedings of the International Federation for Information Processor (IFIP), 1475-1478

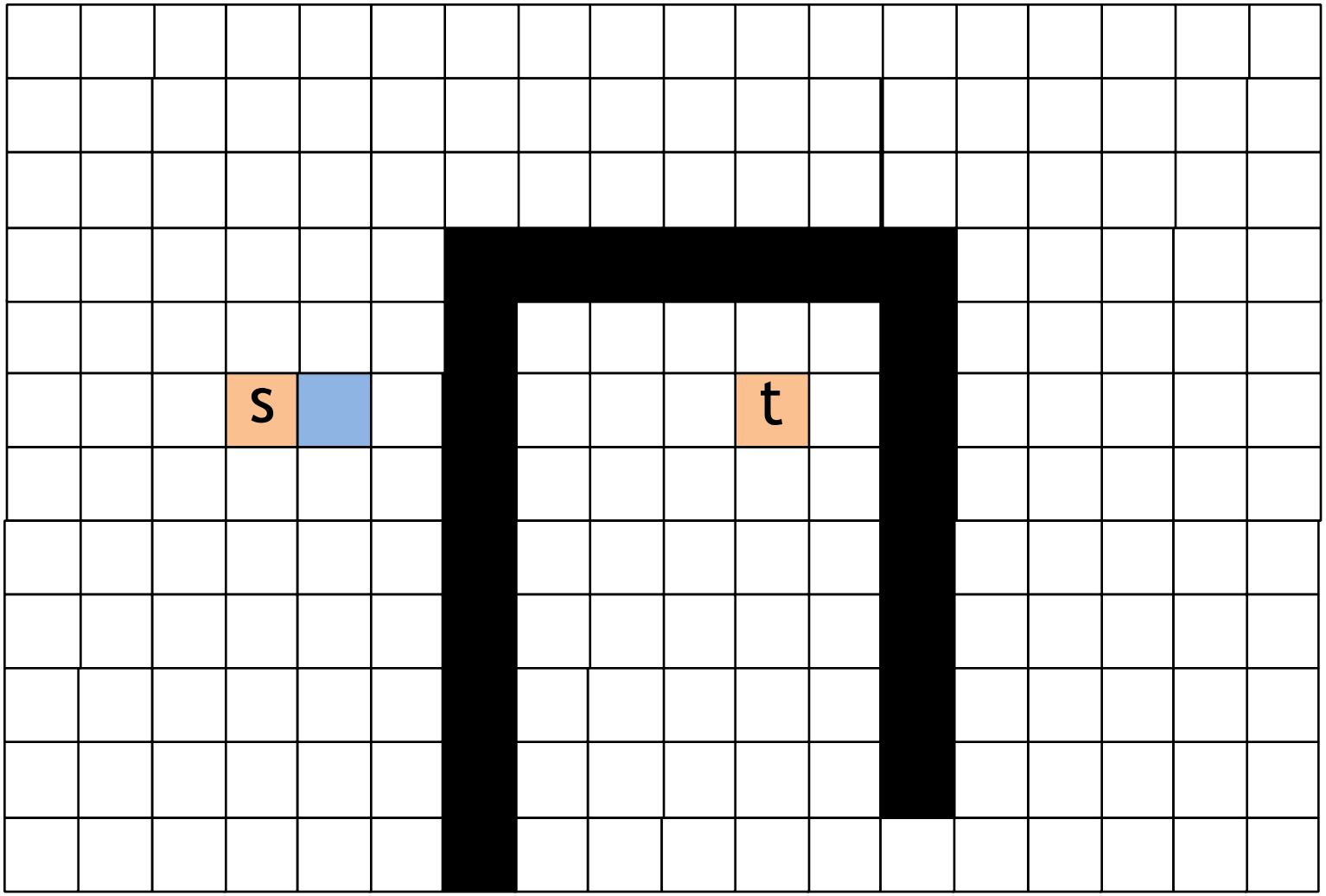
Mikami-Tabuchi Algorithm

- Generate line probes to search
  - Alternative to breadth-first search expansion
  - Can lead to faster escape from blocked regions
- Simultaneously search from source and sink
  - Stop at the intersection point
- Time complexity is O(L), where L is the number of line segments
  - However, L = O(MN) in the worst case

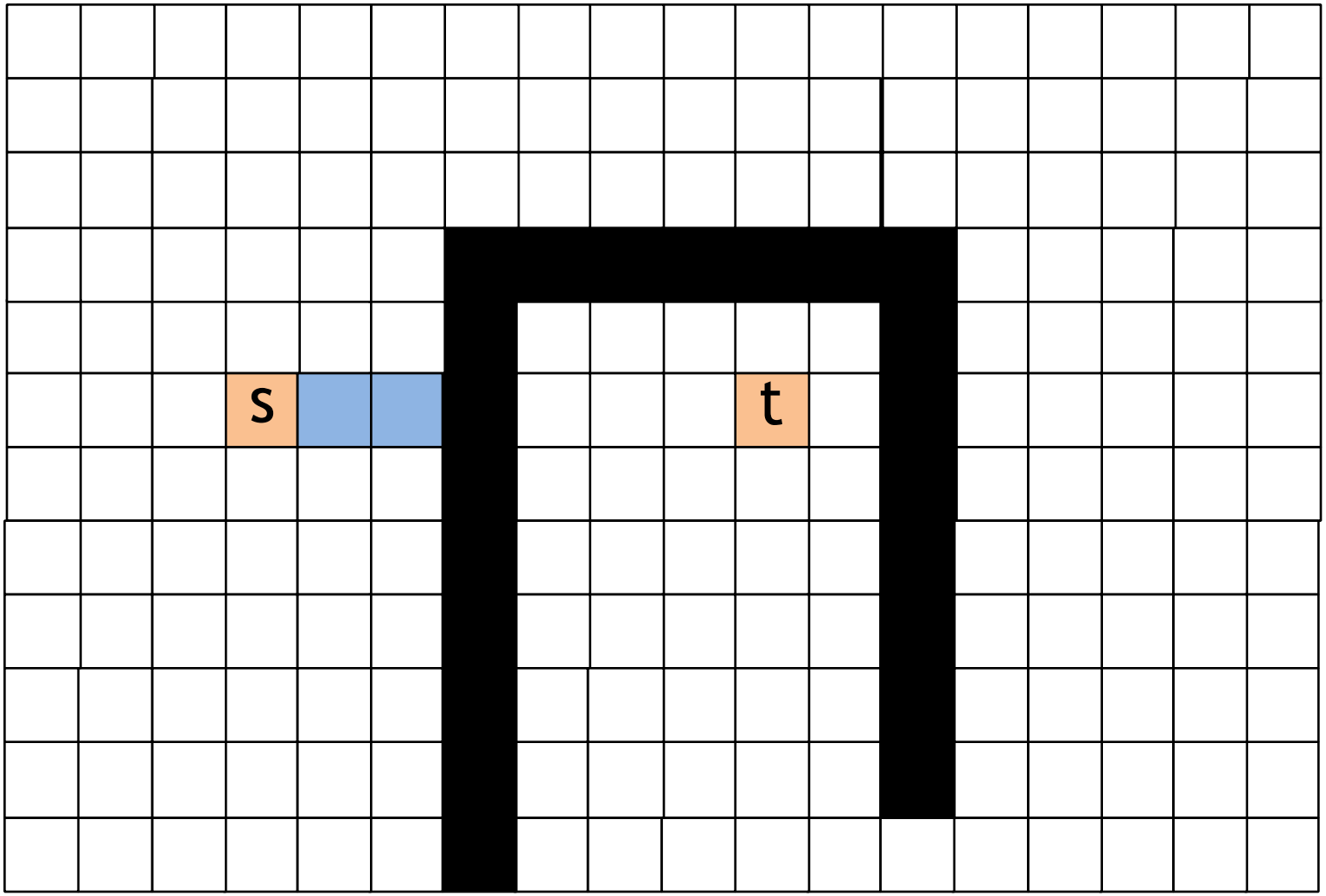
Example



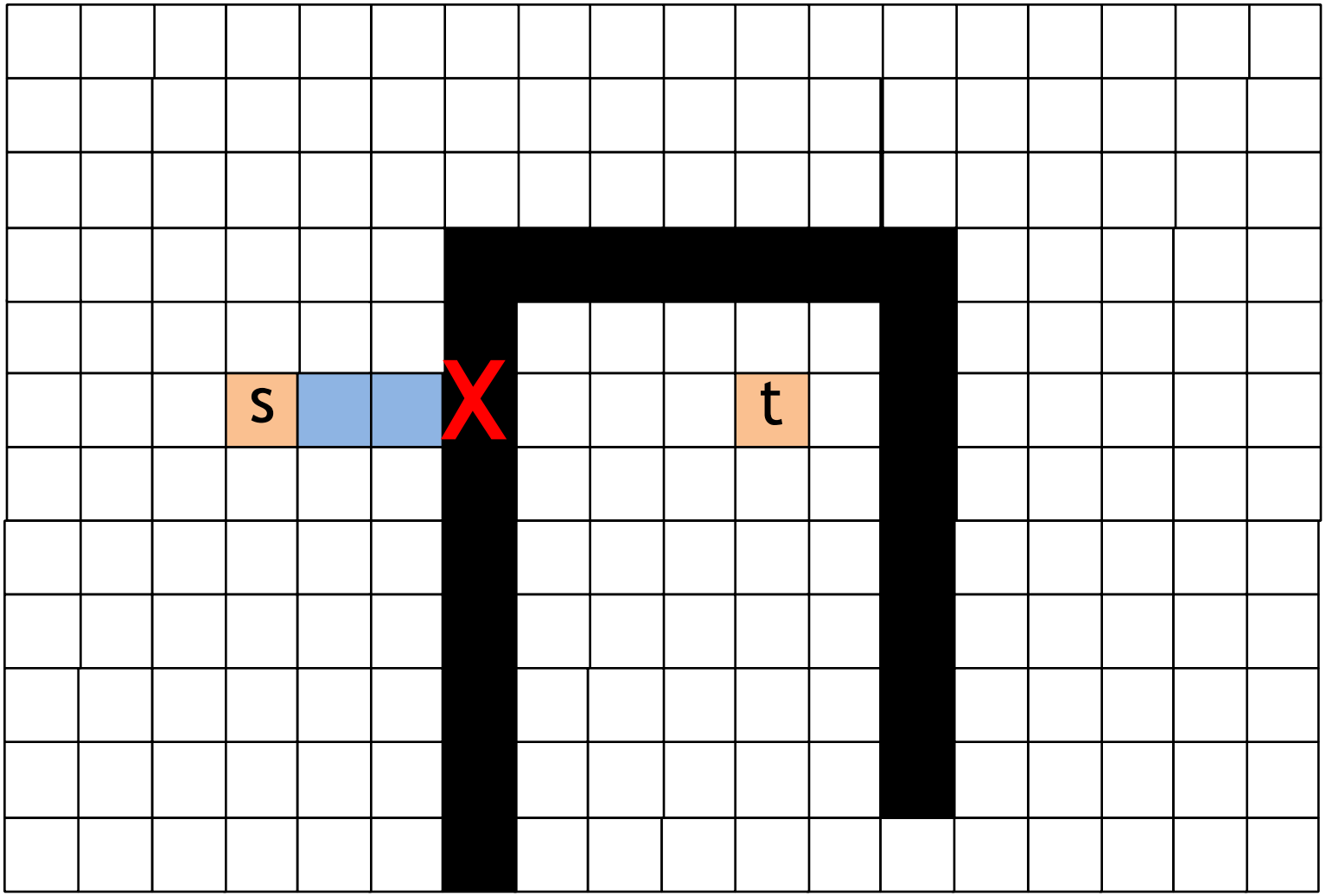
Source Line Probe (Level 0)



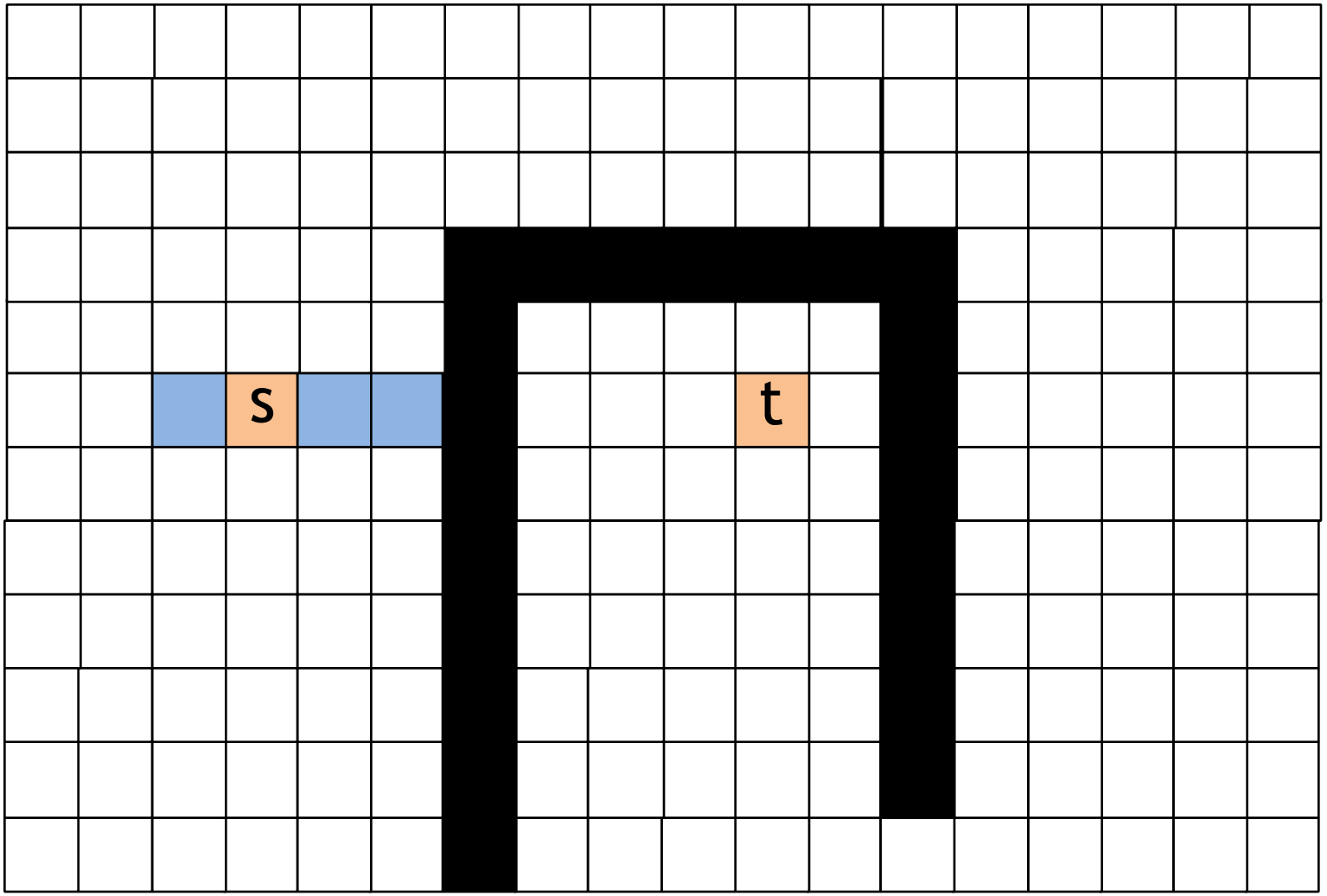
Source Line Probe (Level 0)



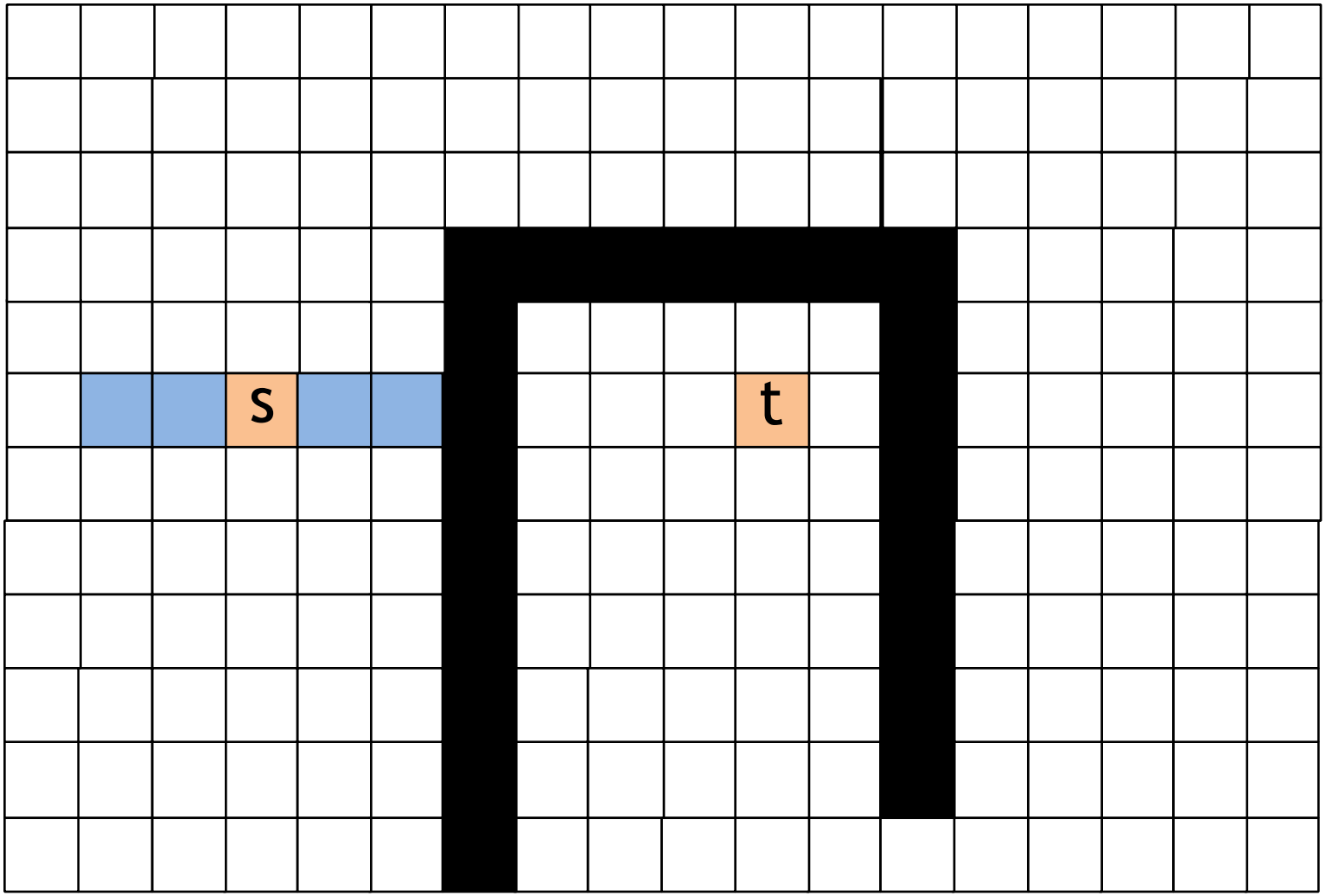
Source Line Probe (Level 0)



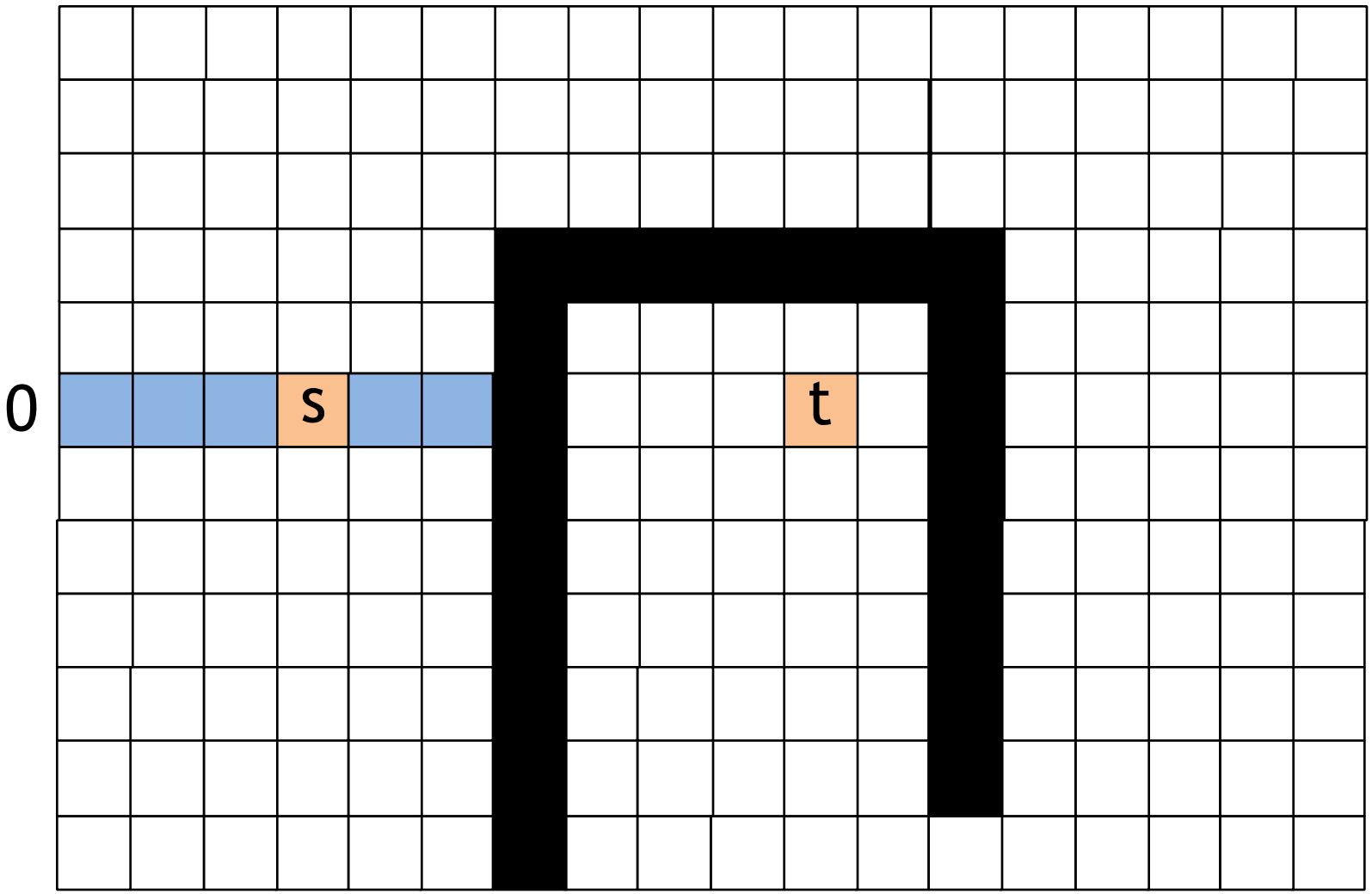
Source Line Probe (Level 0)



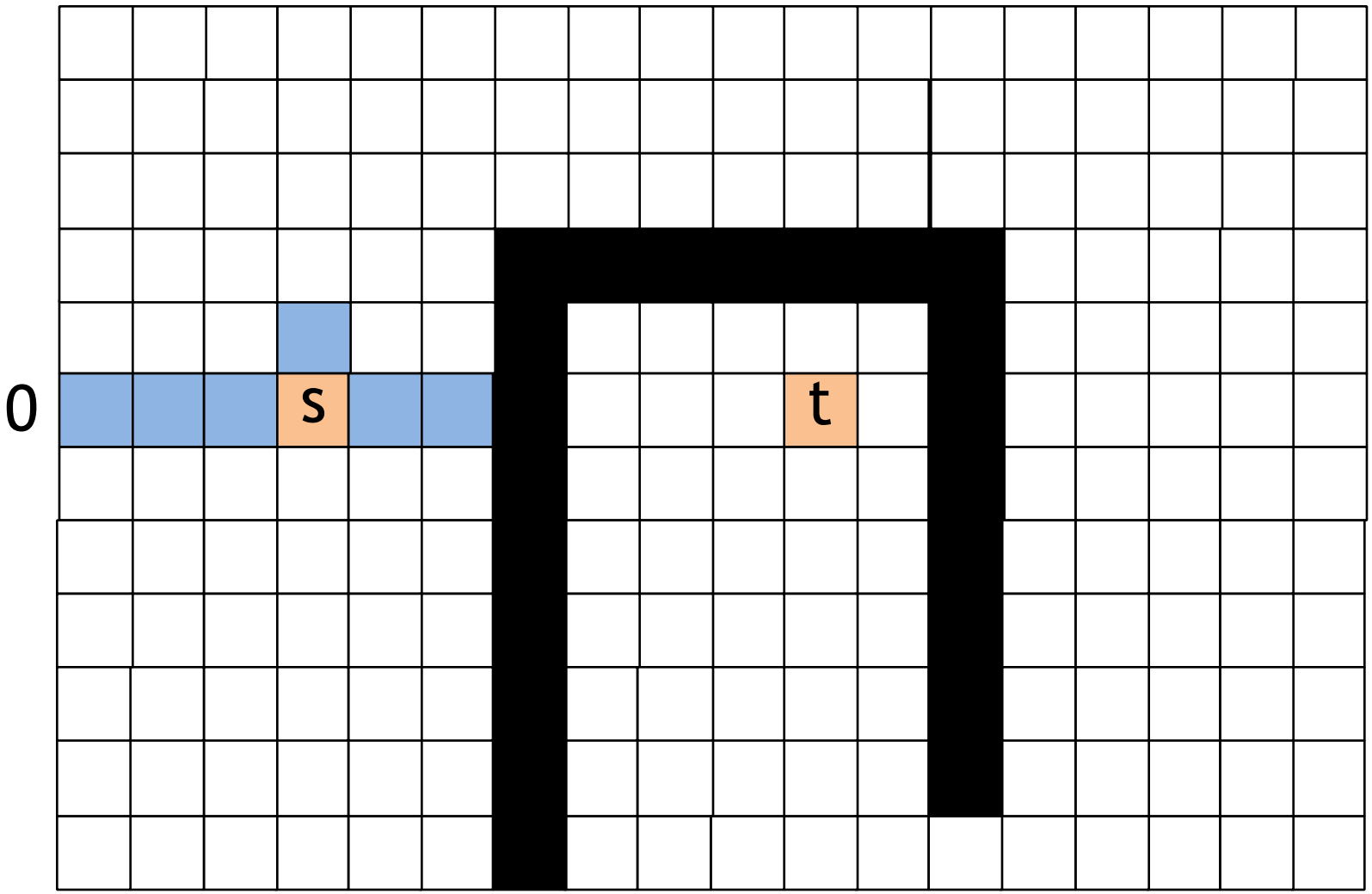
Source Line Probe (Level 0)



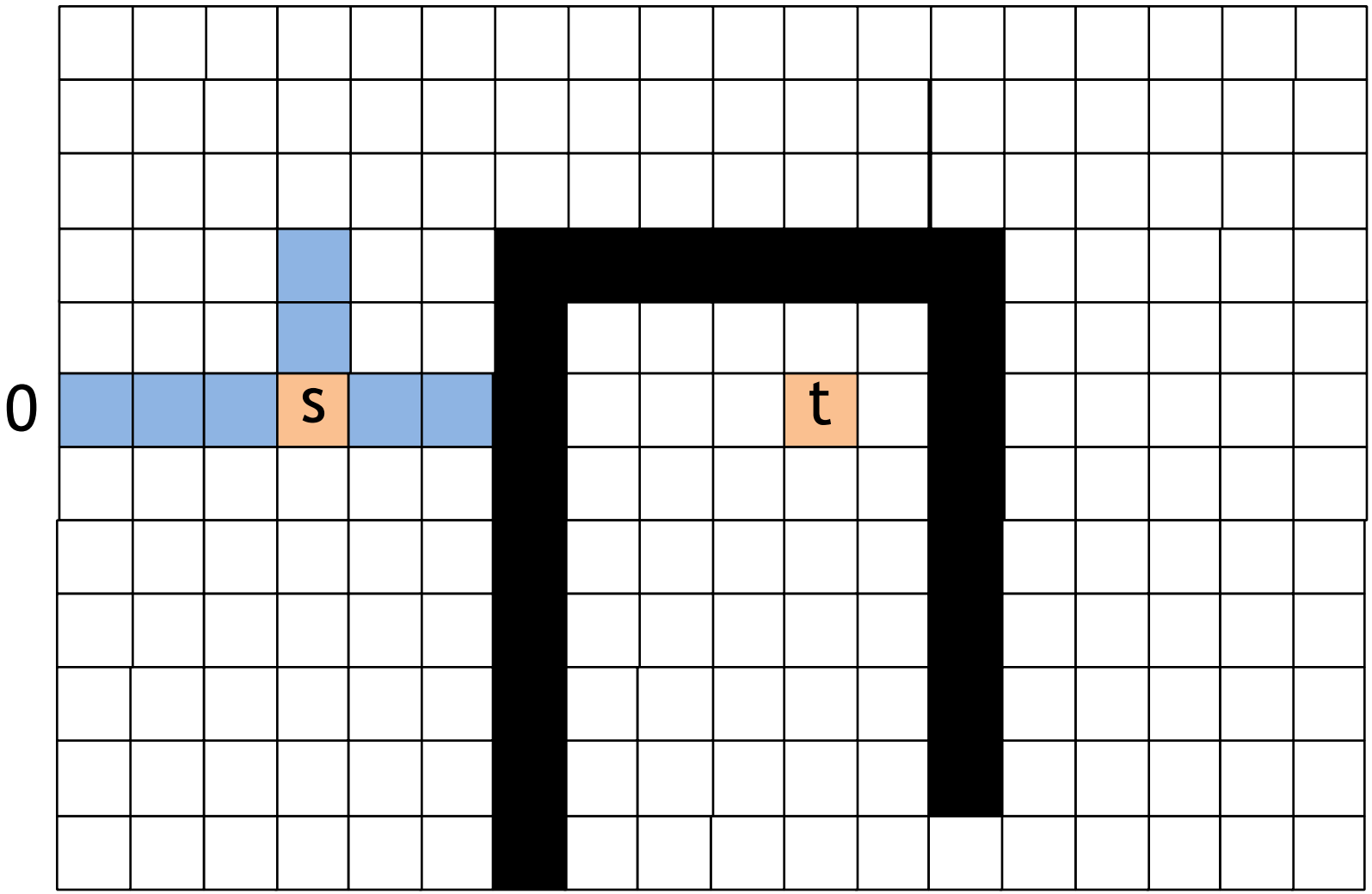
Source Line Probe (Level 0)



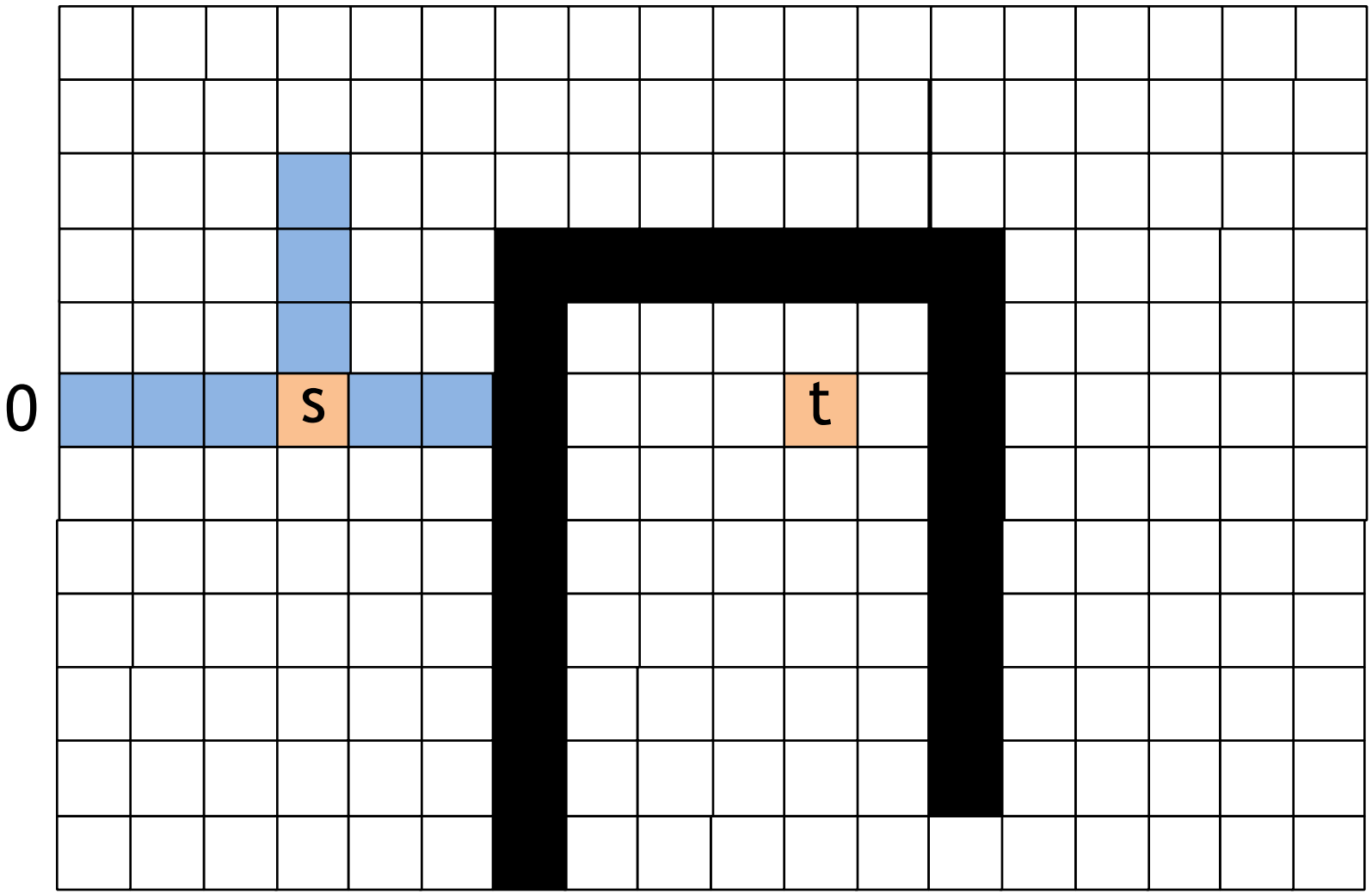
Source Line Probe (Level 0)



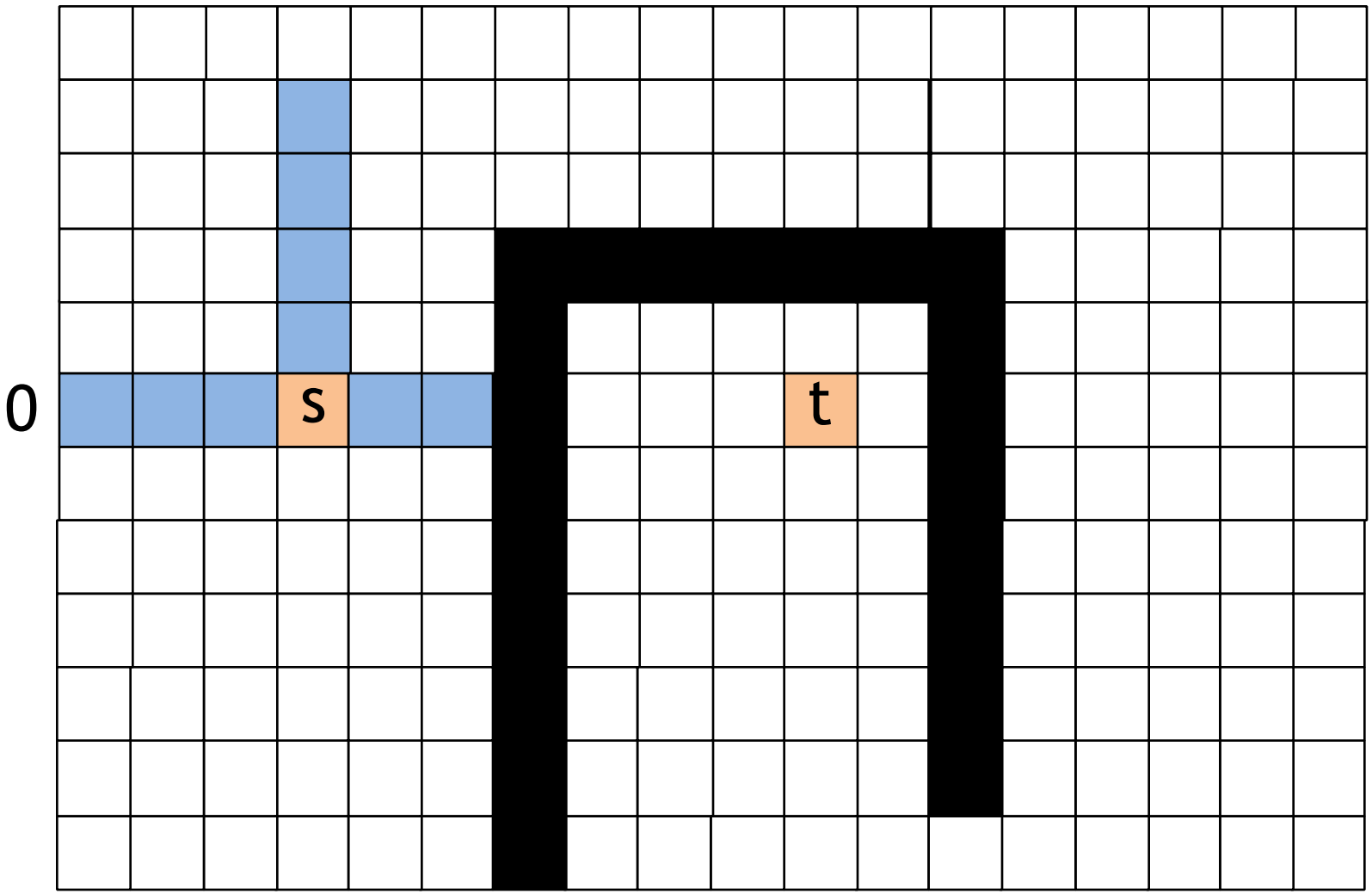
Source Line Probe (Level 0)



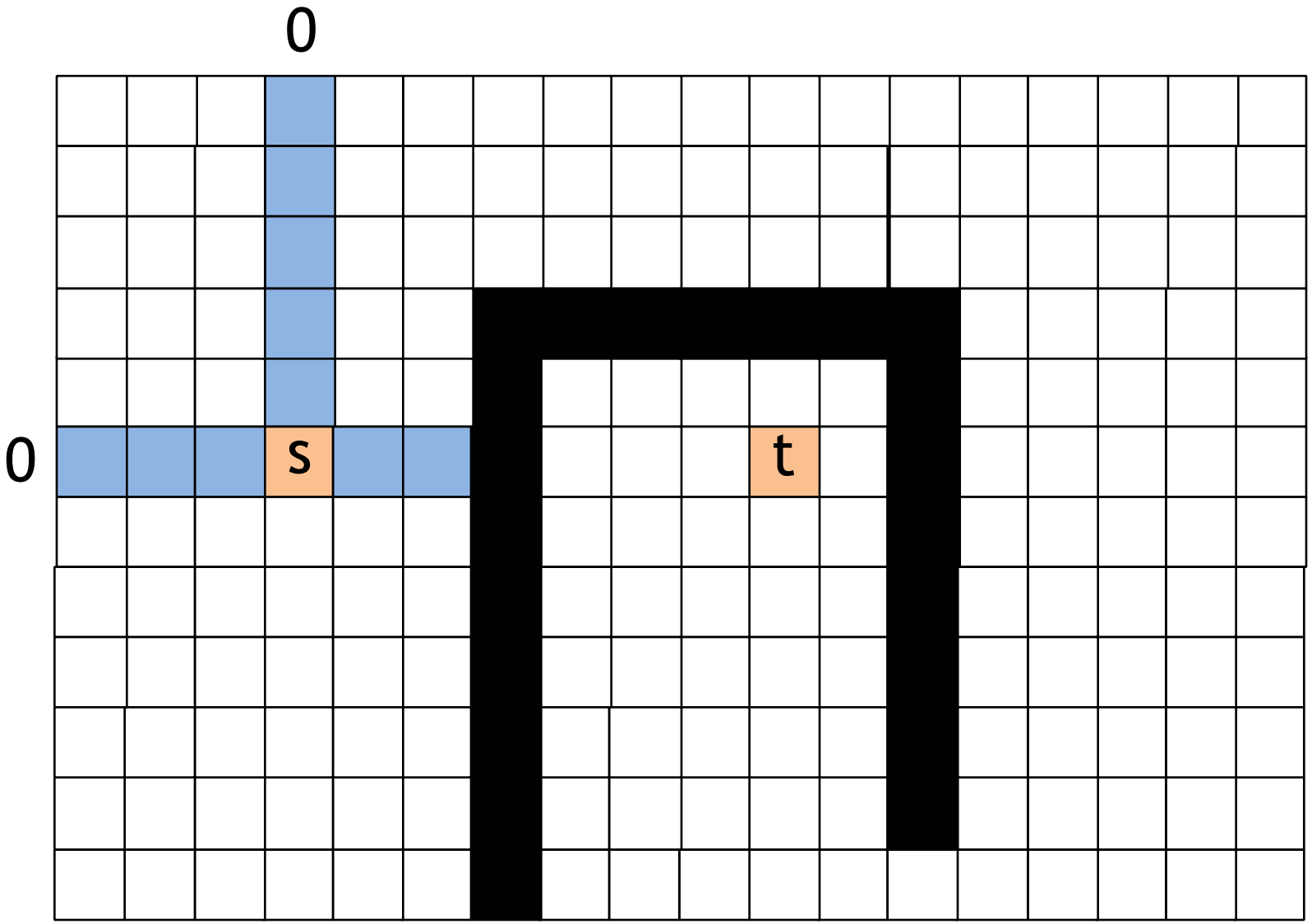
Source Line Probe (Level 0)



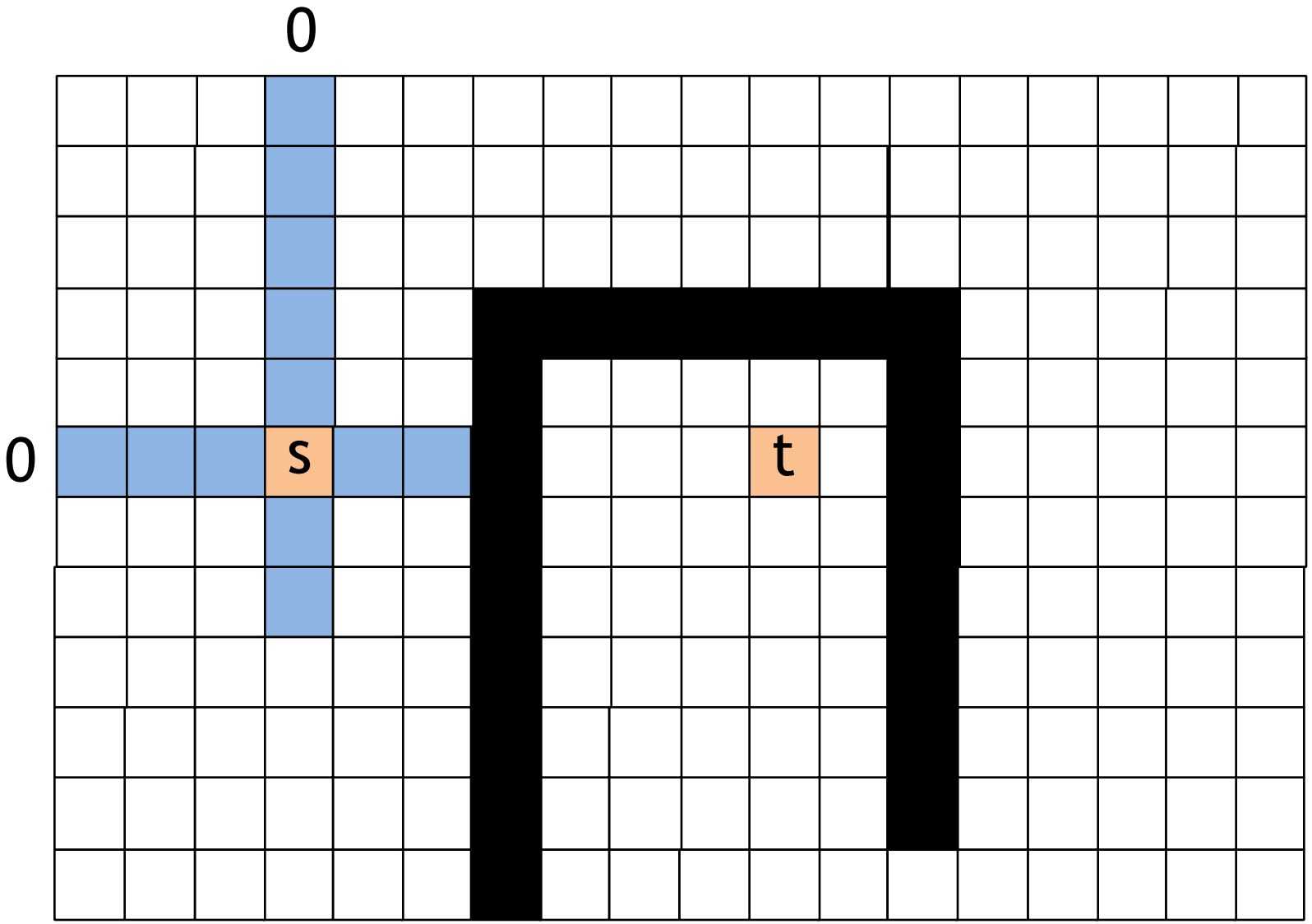
Source Line Probe (Level 0)



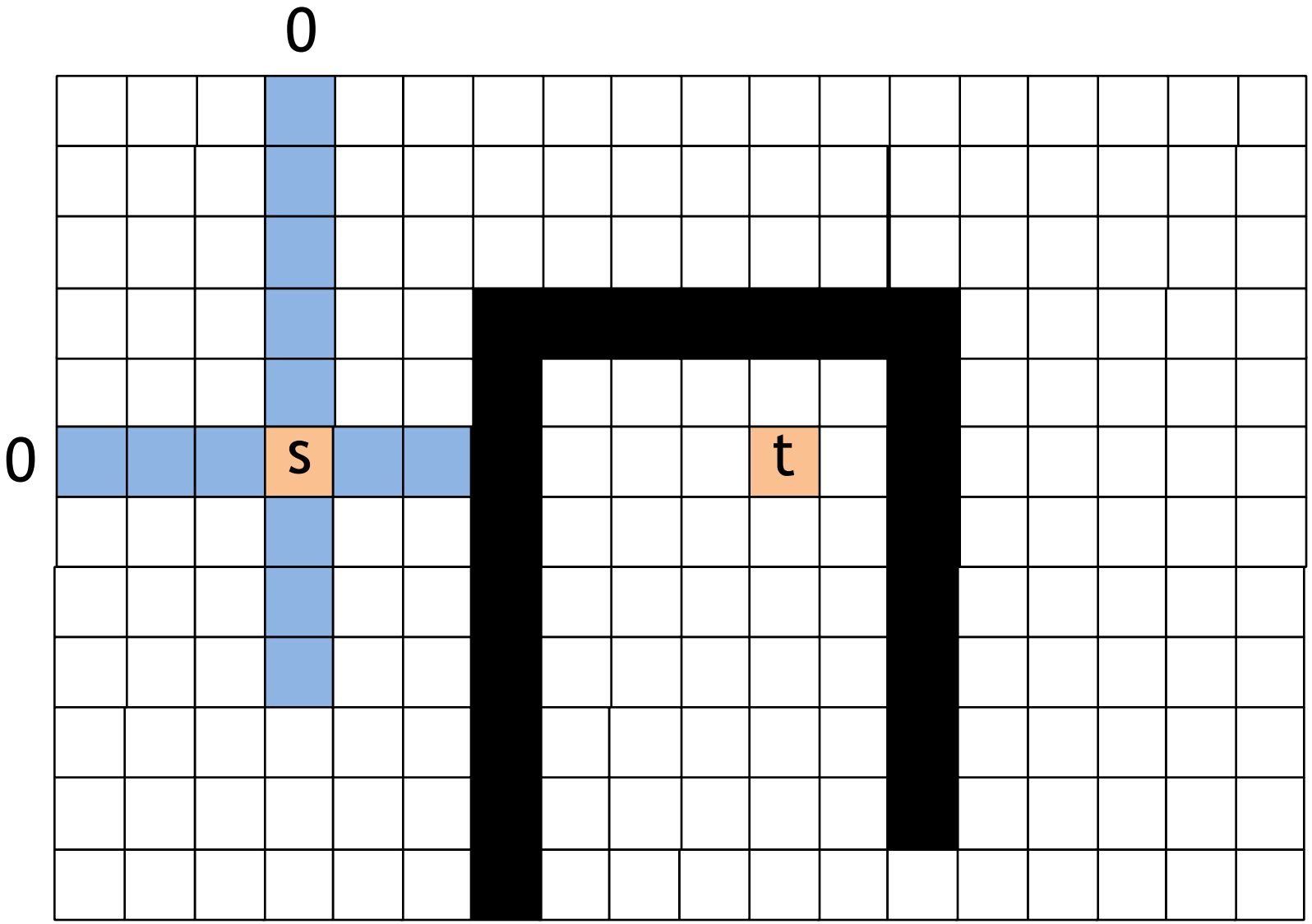
Source Line Probe (Level 0)



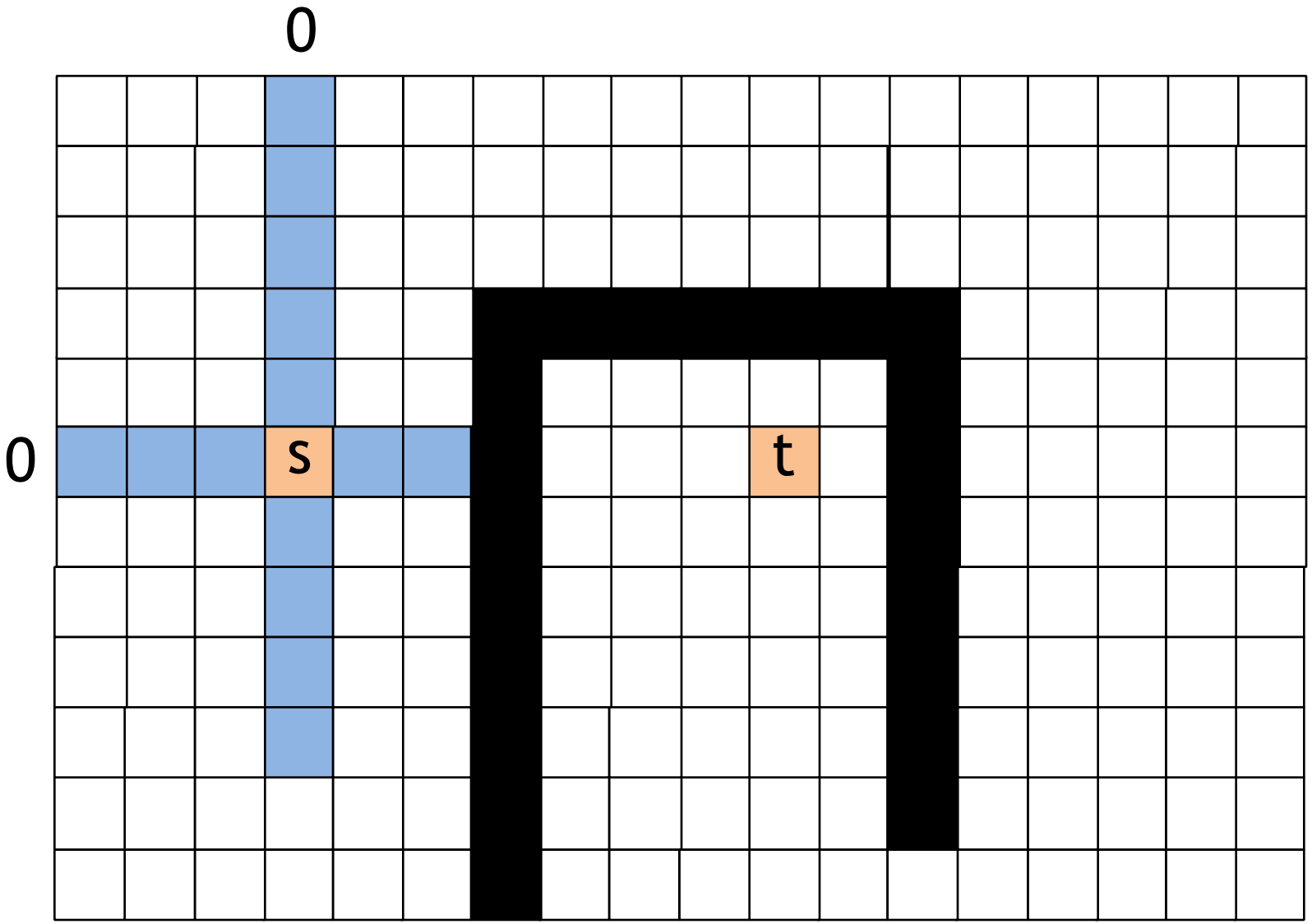
Source Line Probe (Level 0)



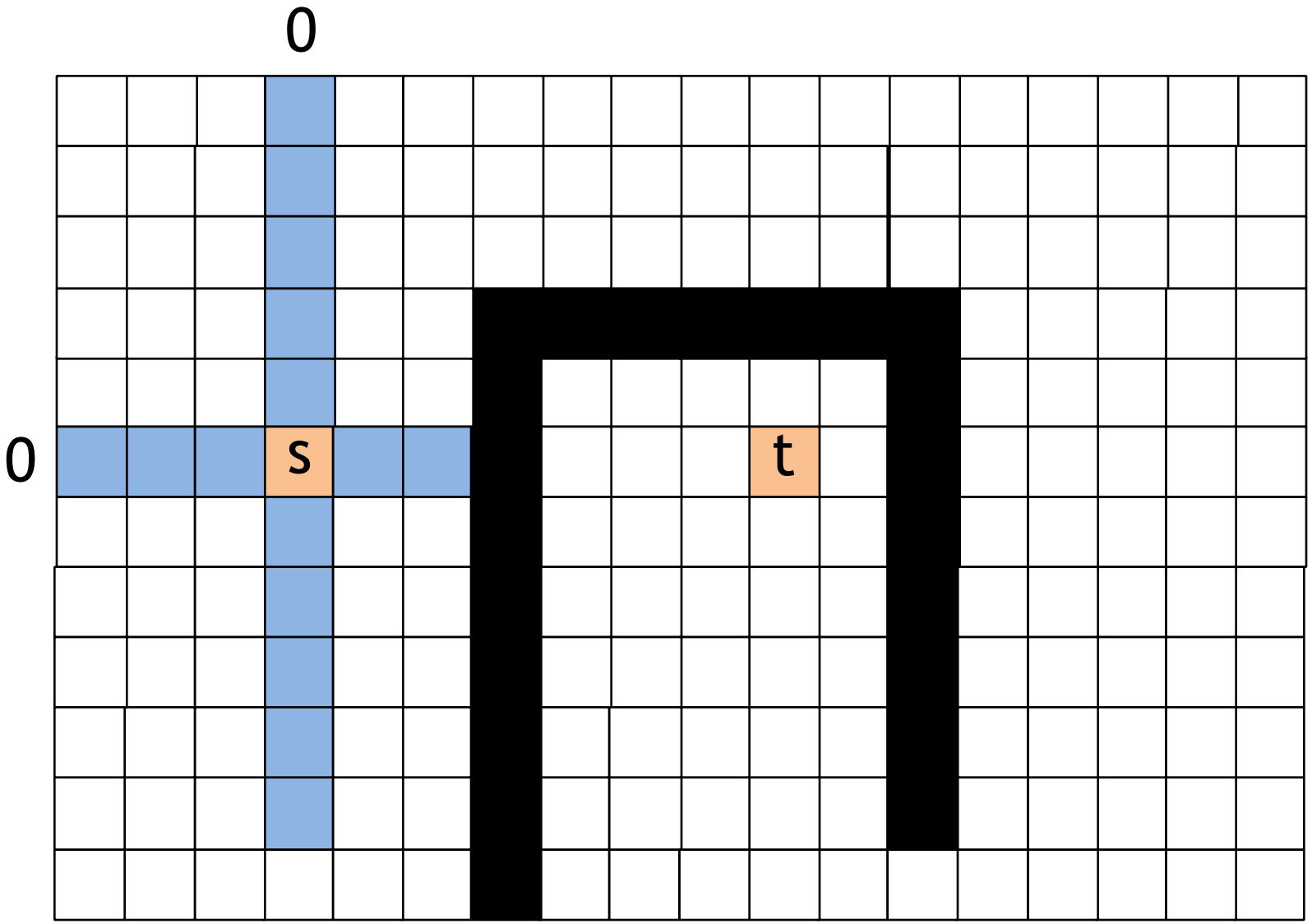
Source Line Probe (Level 0)



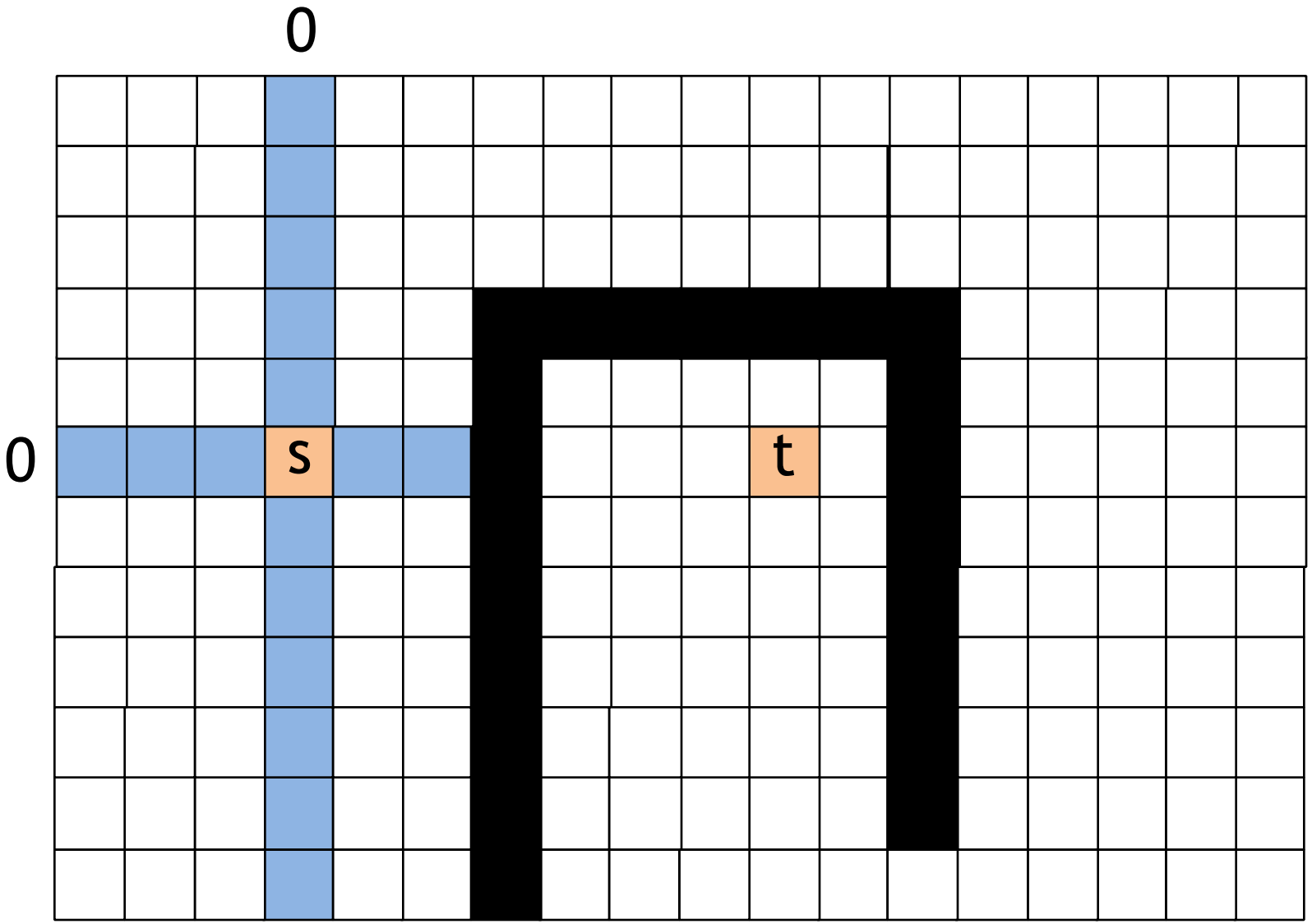
Source Line Probe (Level 0)



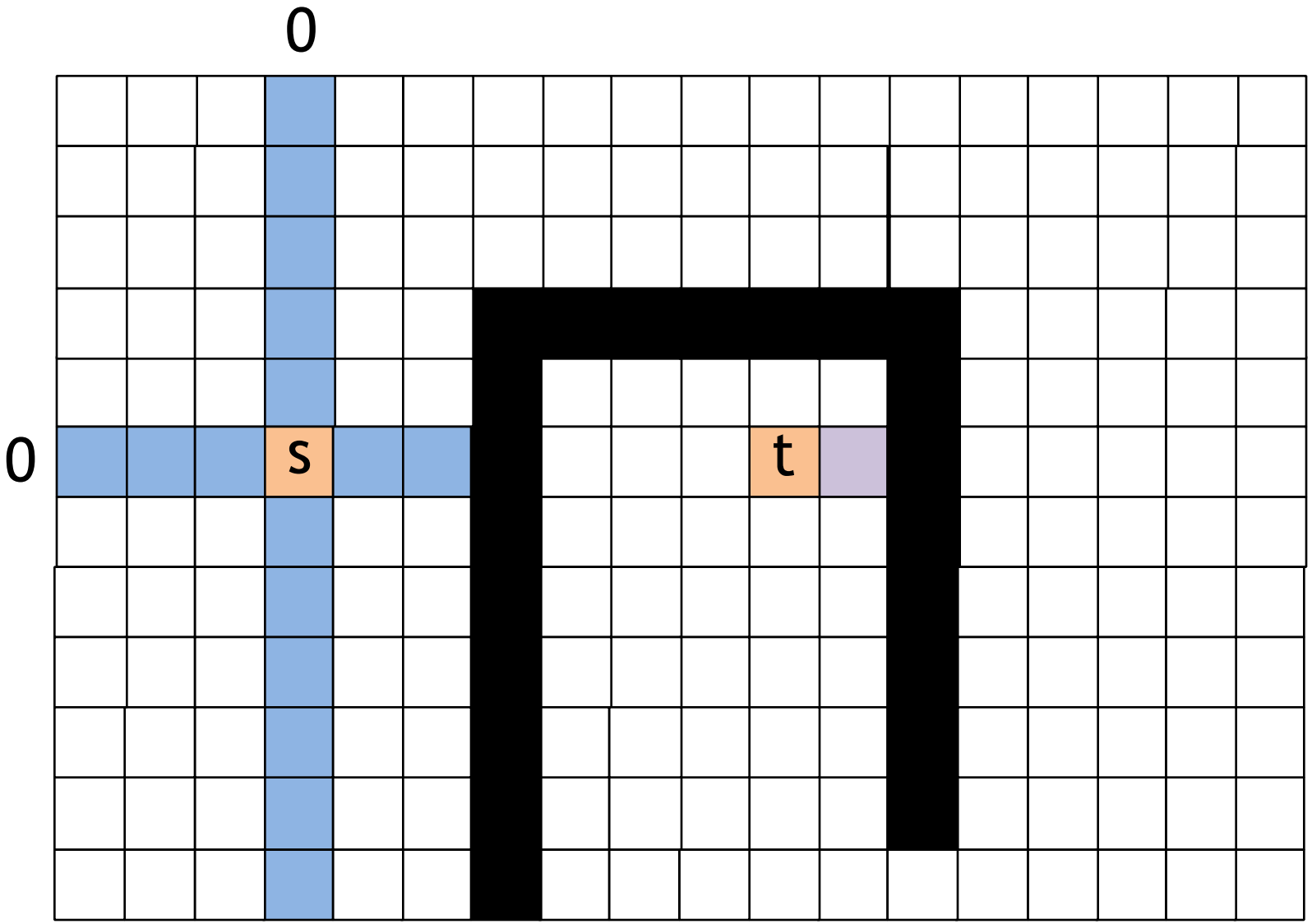
Source Line Probe (Level 0)



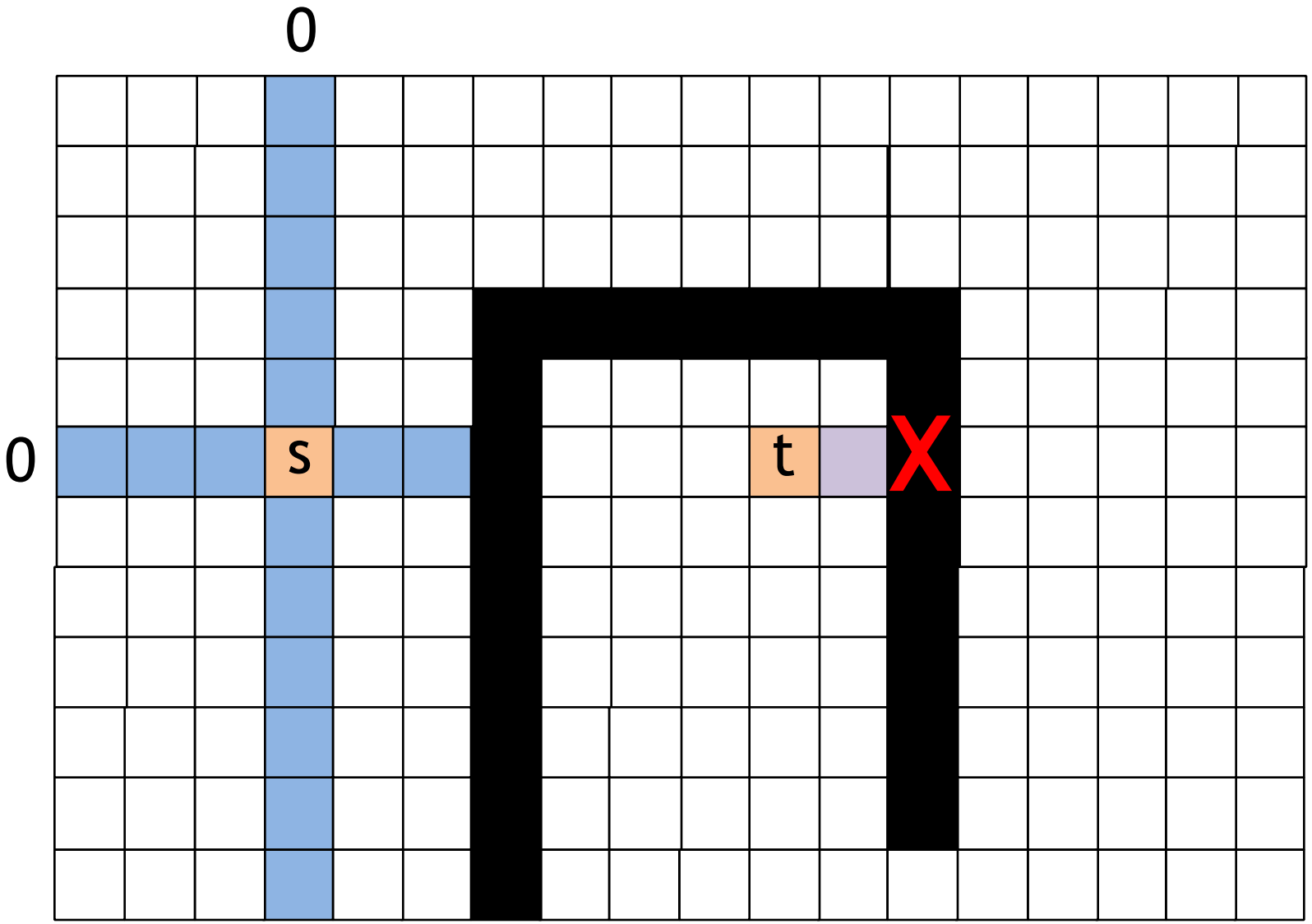
Source Line Probe (Level 0)



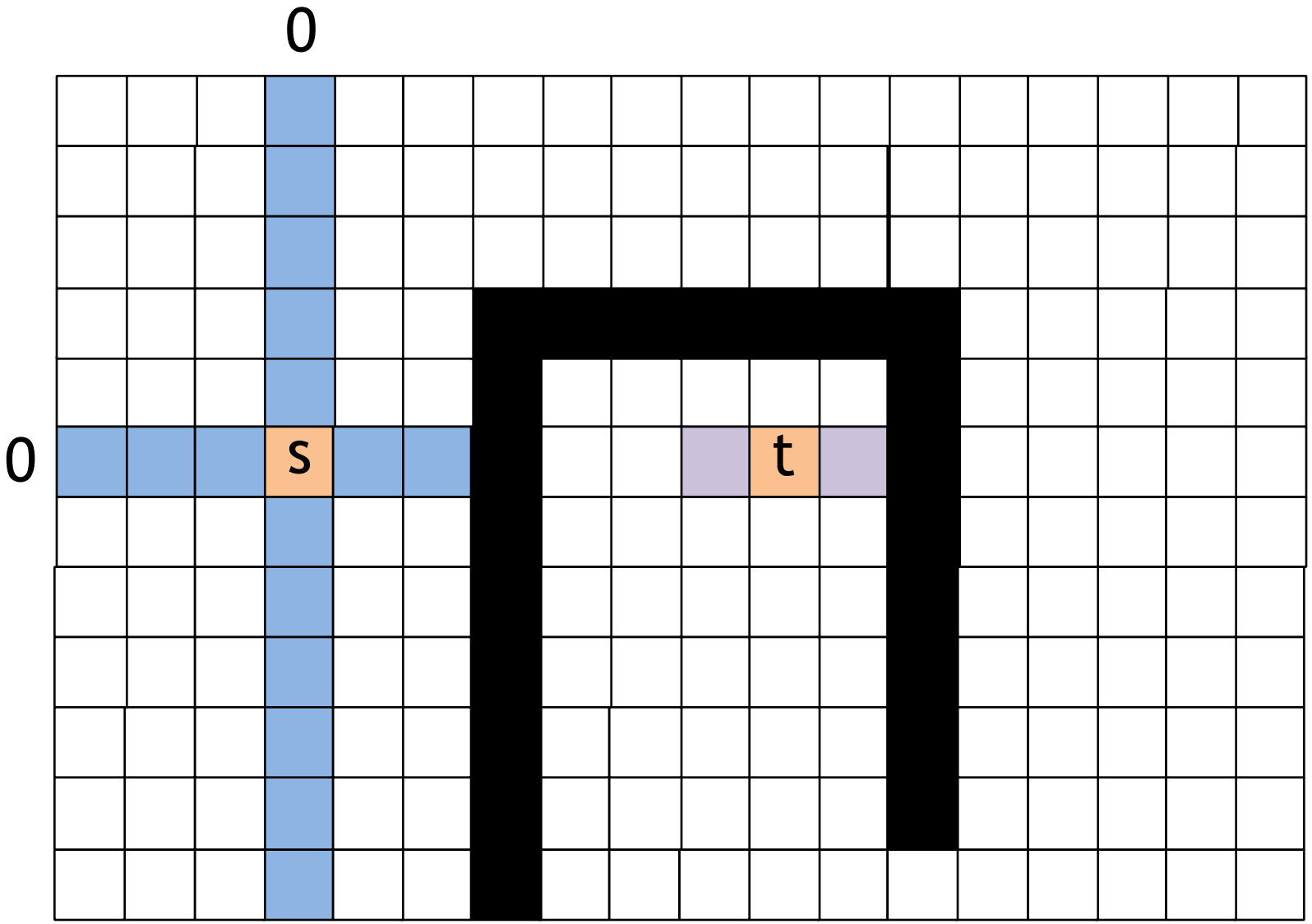
Sink Line Probe (Level 0)



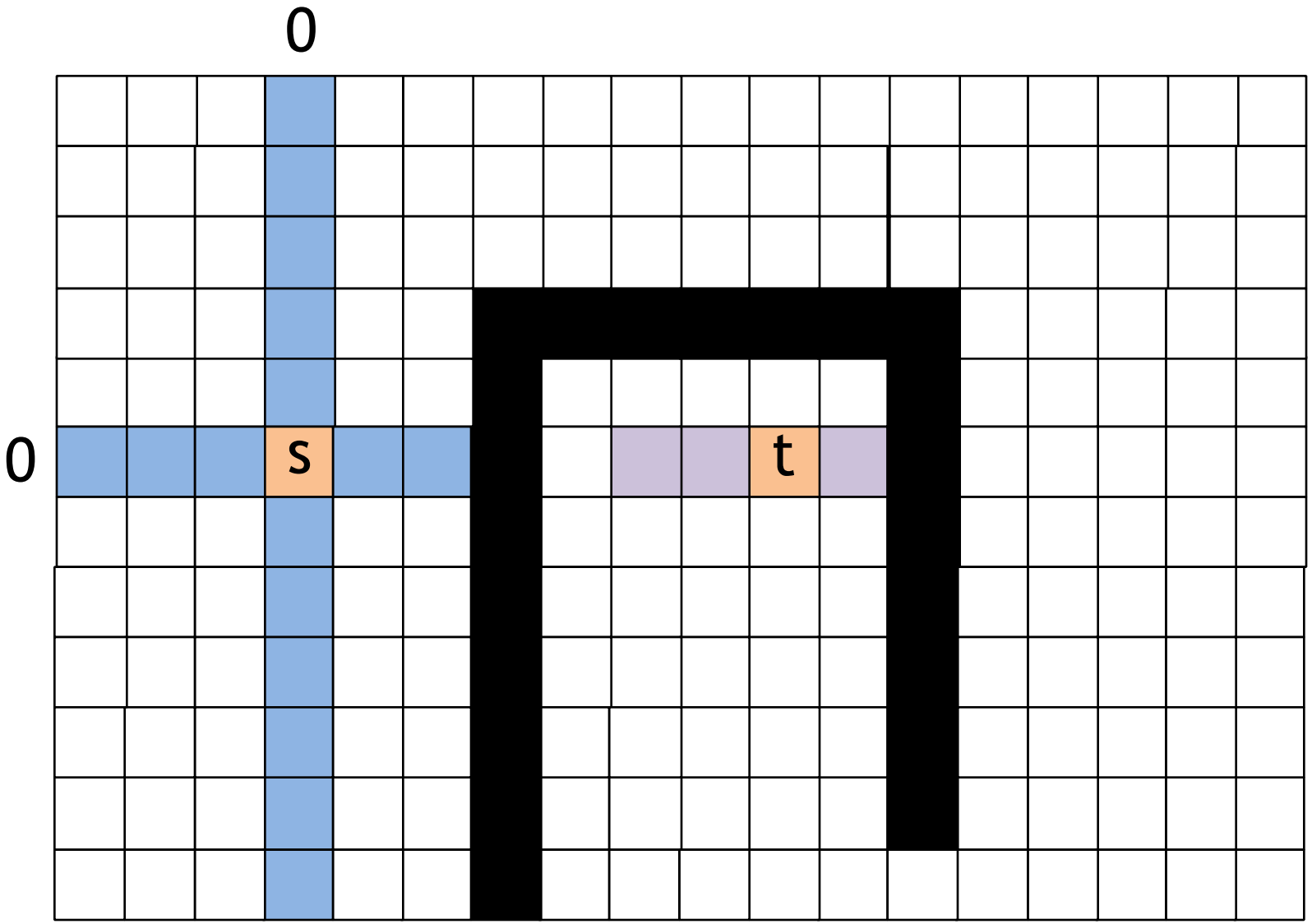
Sink Line Probe (Level 0)



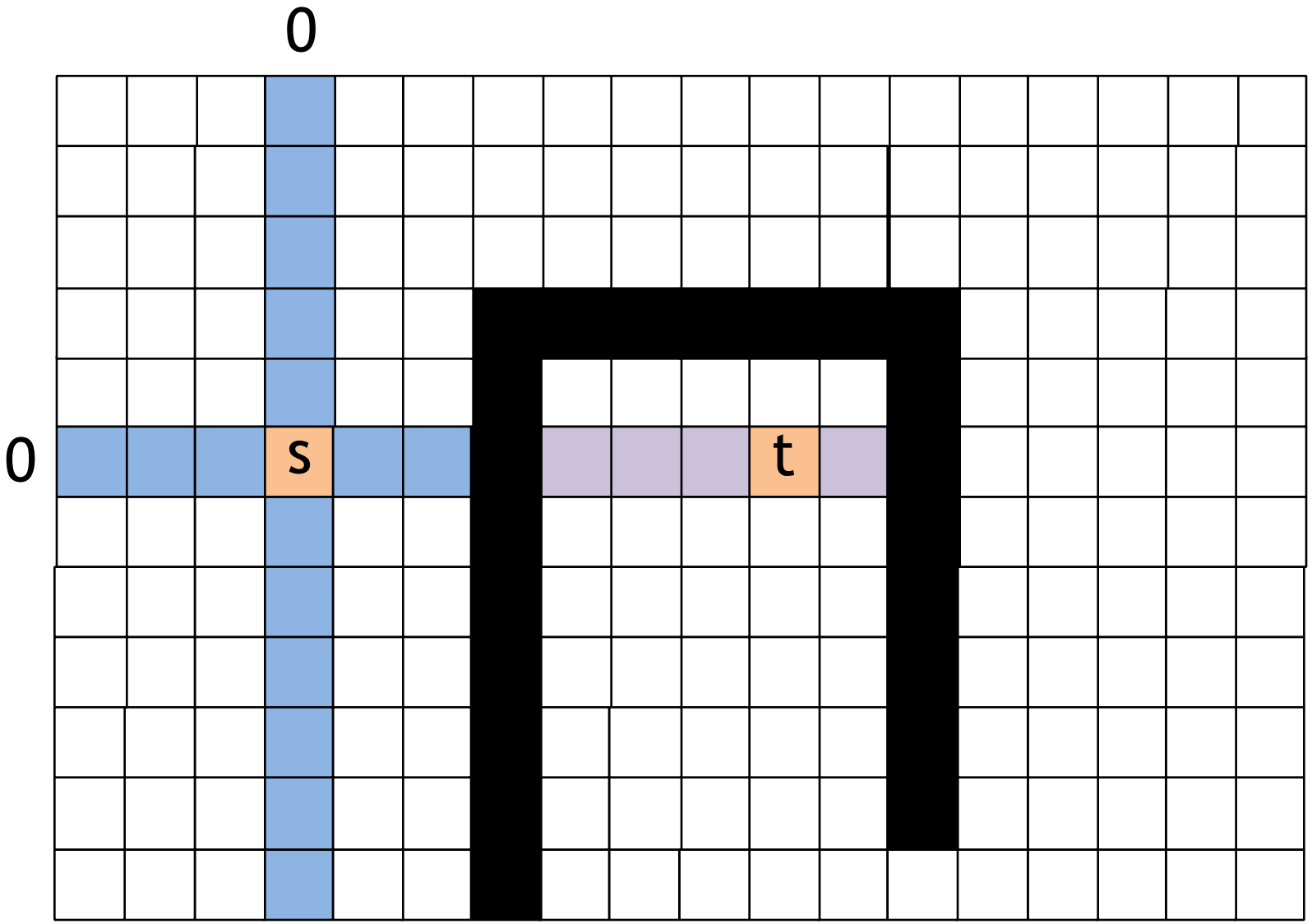
Sink Line Probe (Level 0)



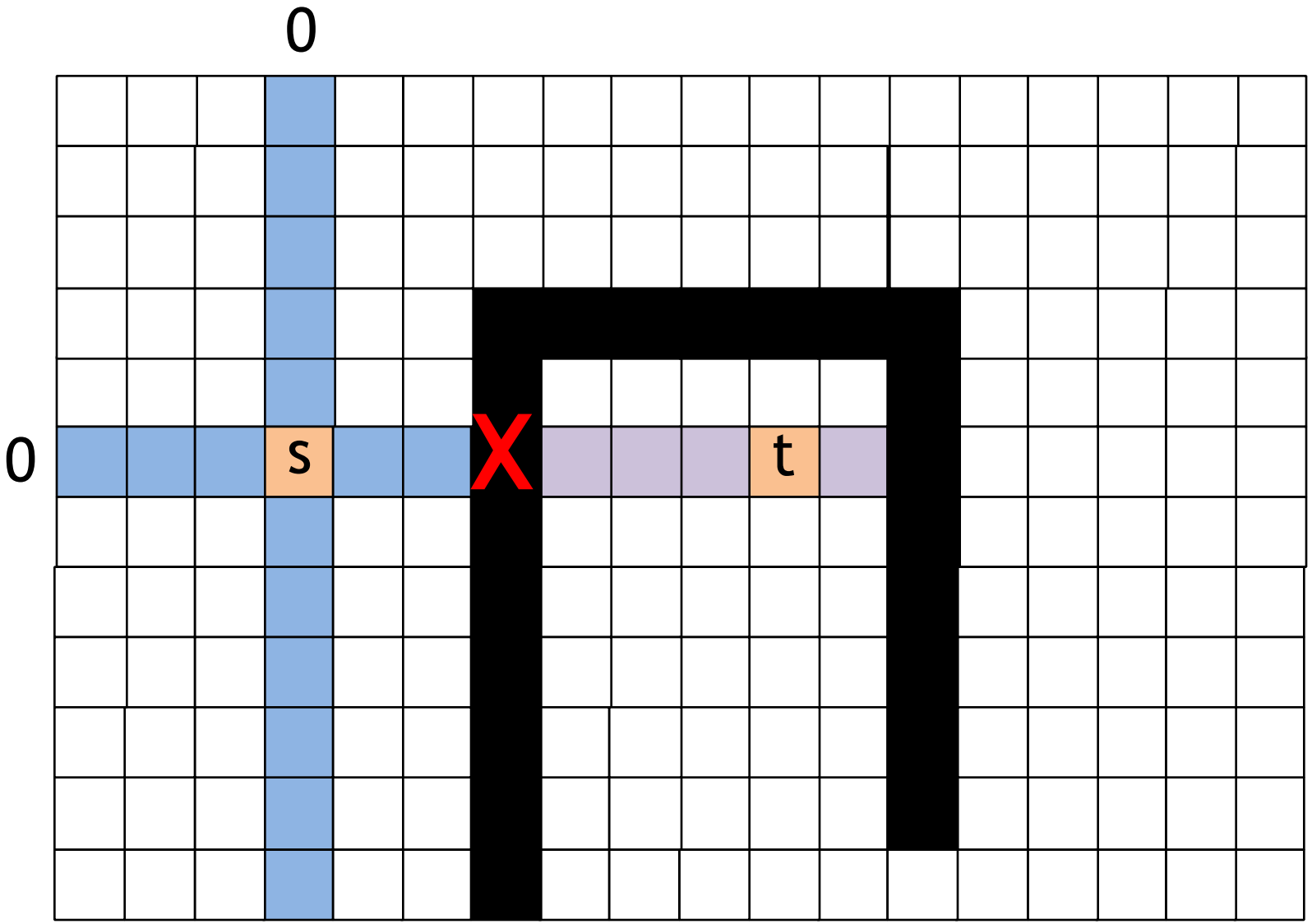
Sink Line Probe (Level 0)



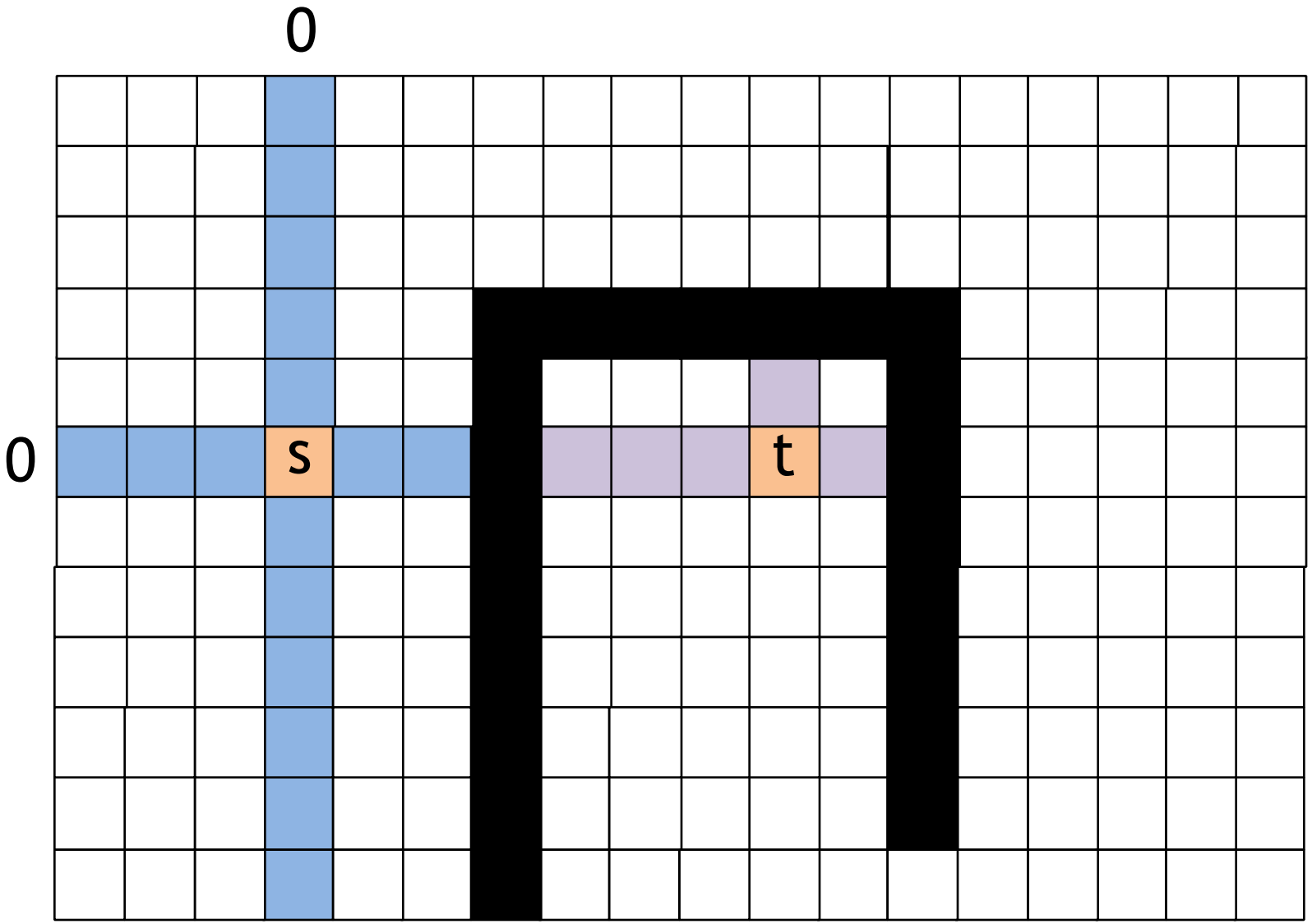
Sink Line Probe (Level 0)



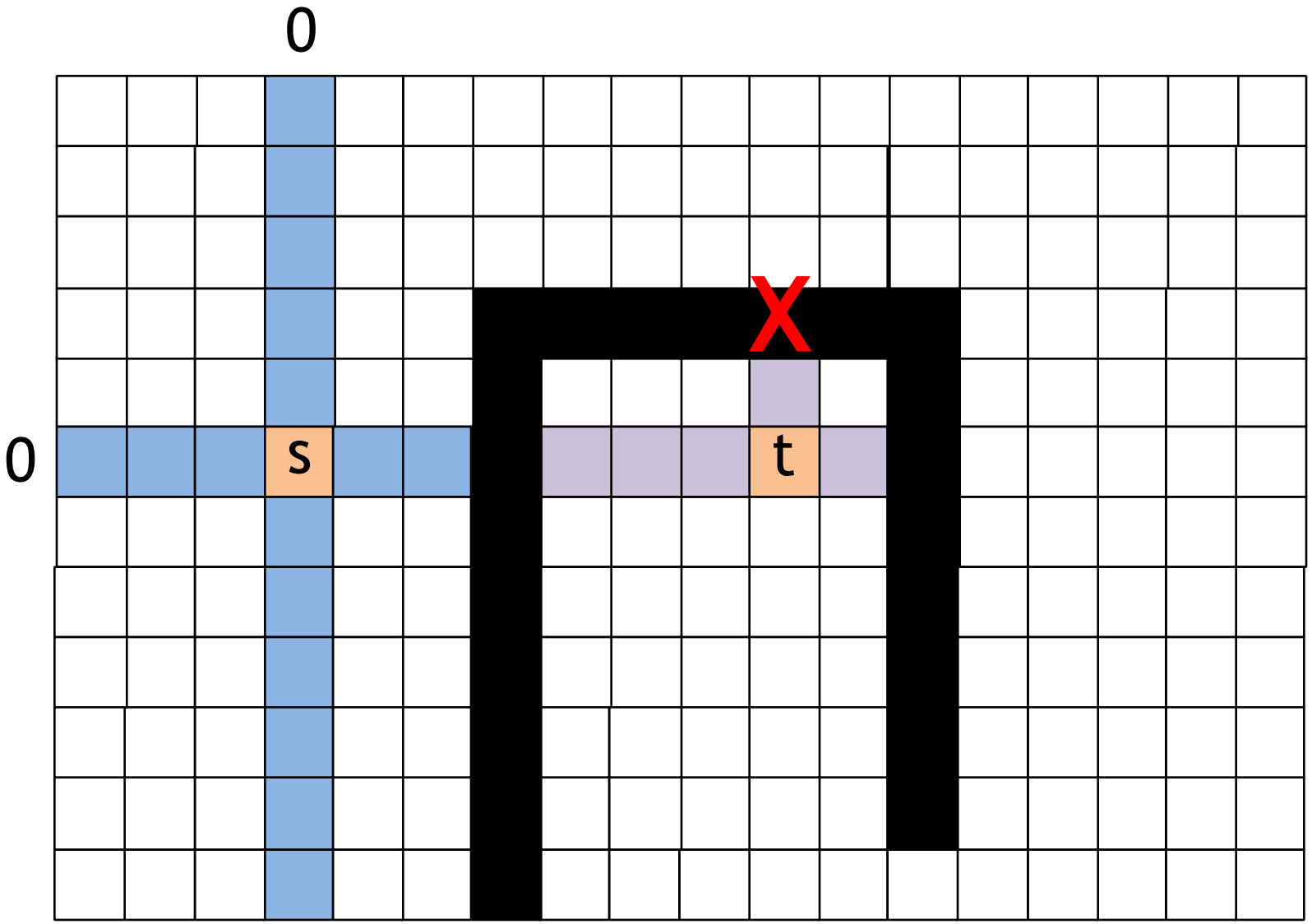
Sink Line Probe (Level 0)



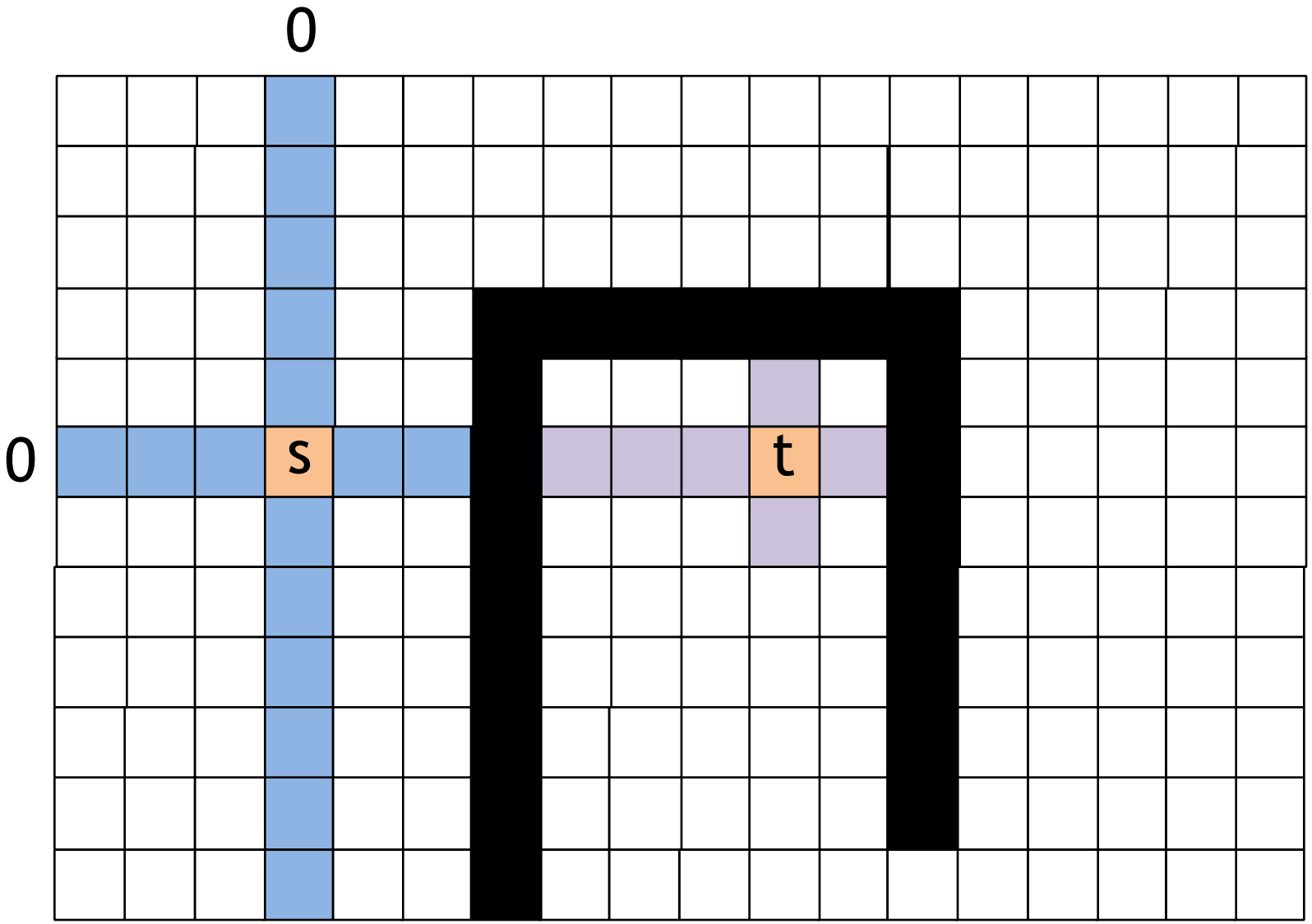
Sink Line Probe (Level 0)



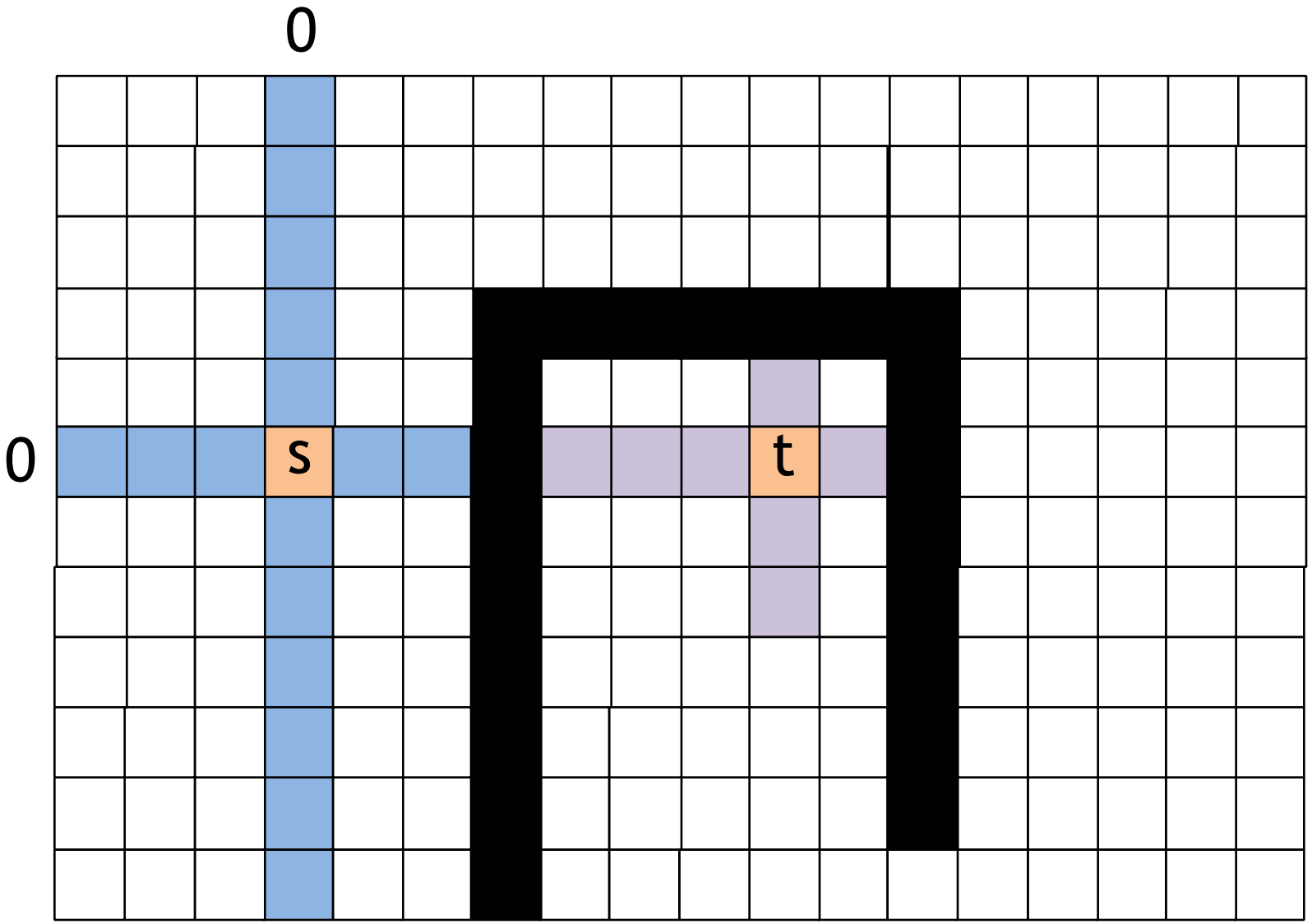
Sink Line Probe (Level 0)



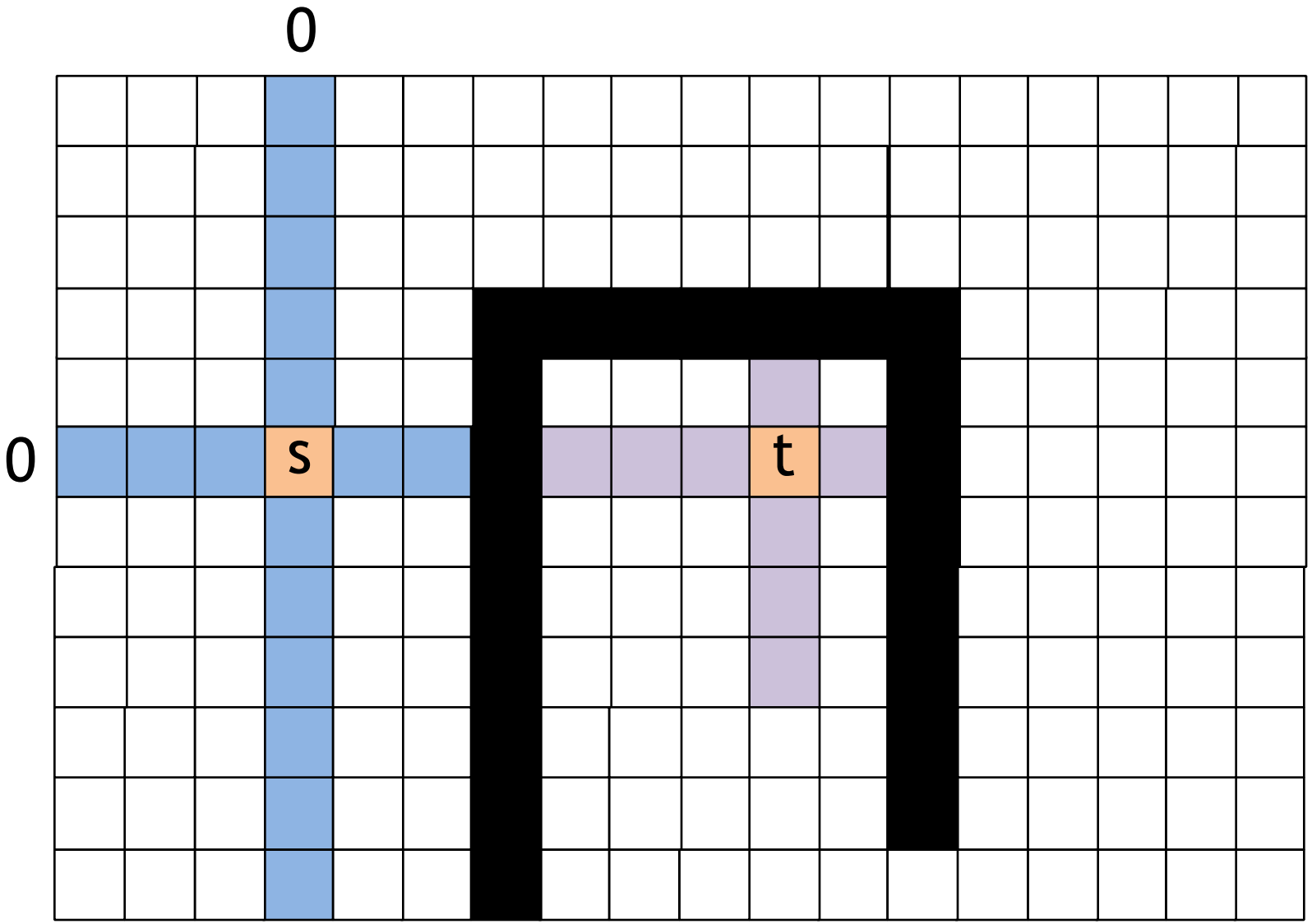
Sink Line Probe (Level 0)



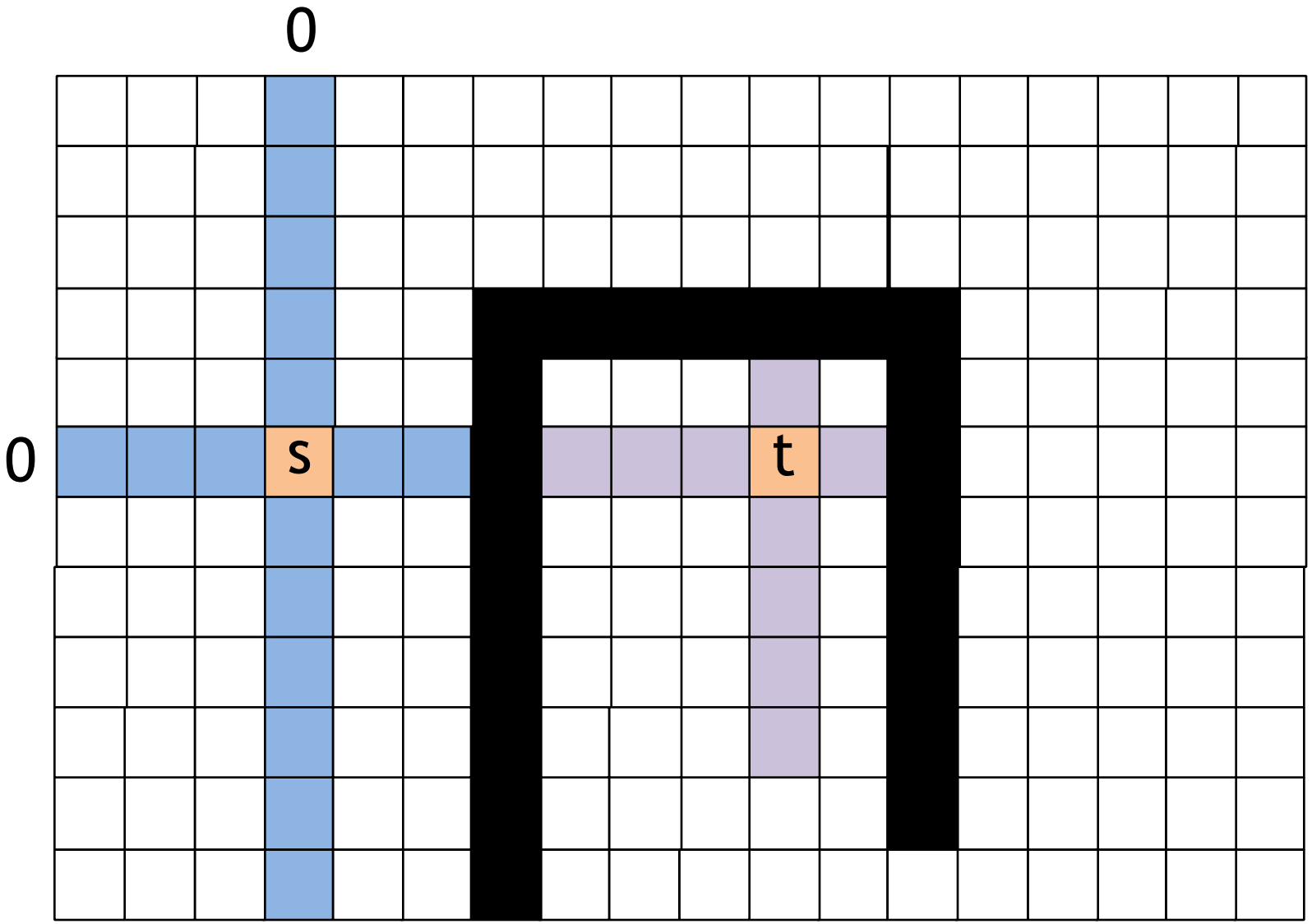
Sink Line Probe (Level 0)



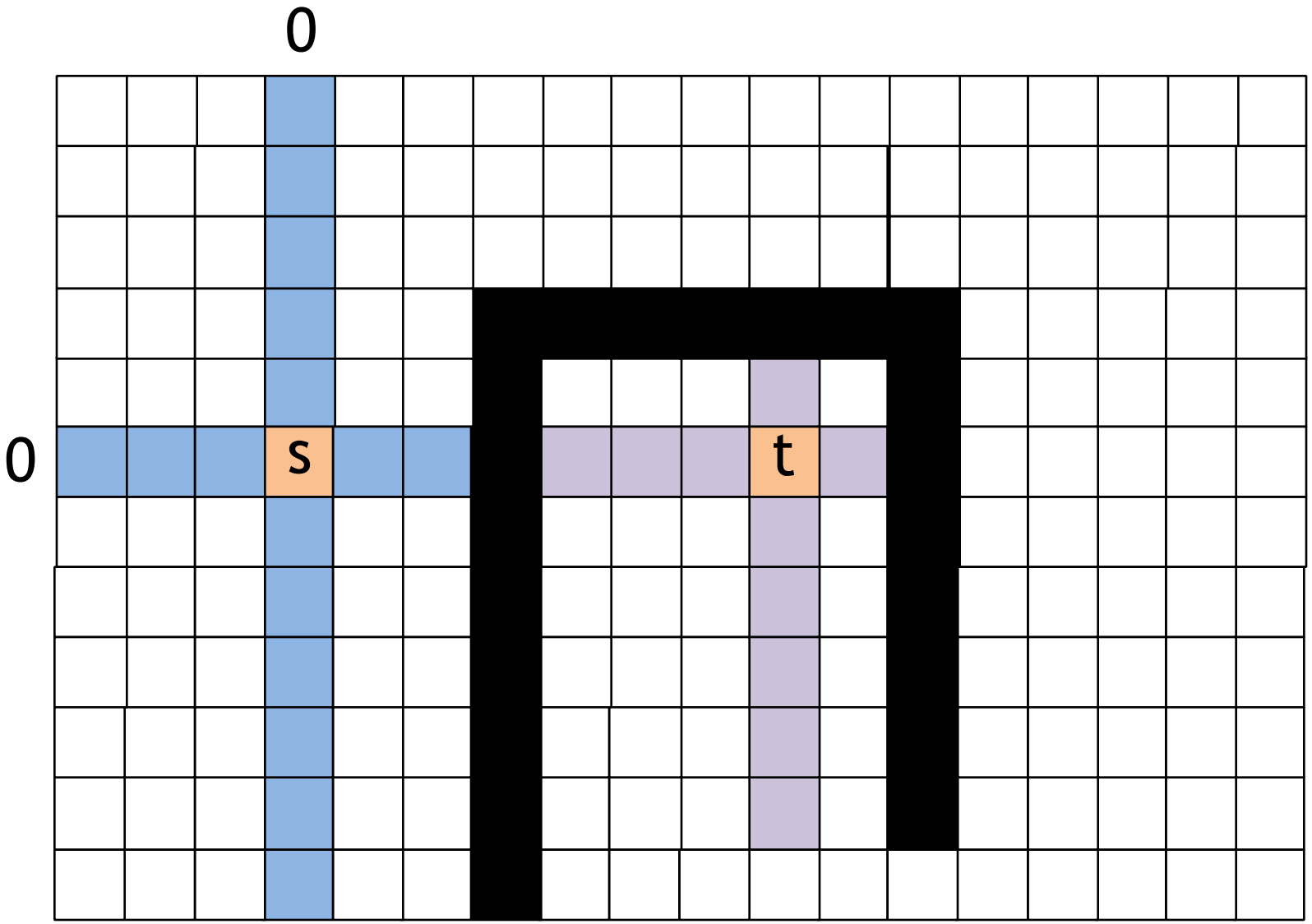
Sink Line Probe (Level 0)



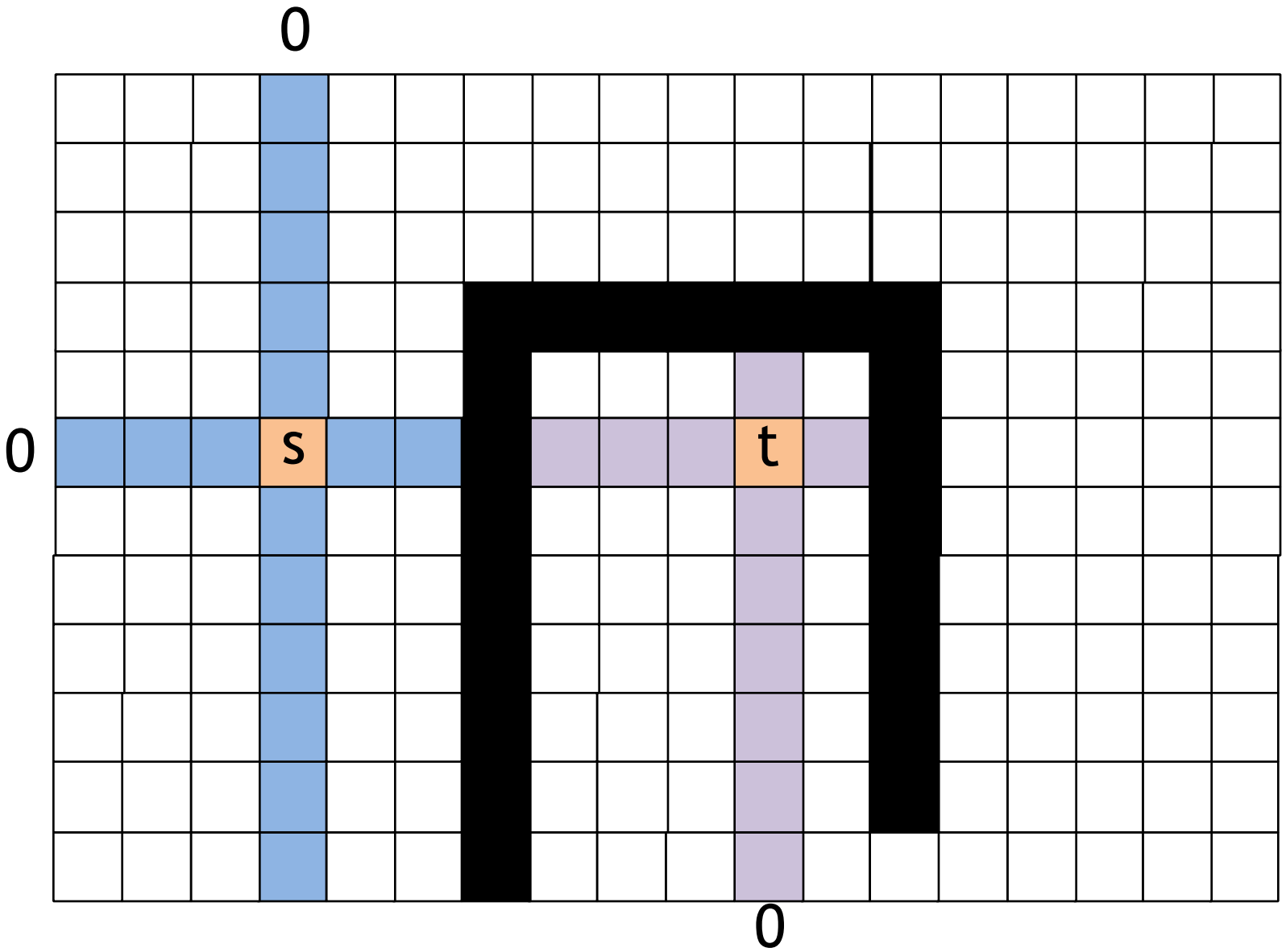
Sink Line Probe (Level 0)



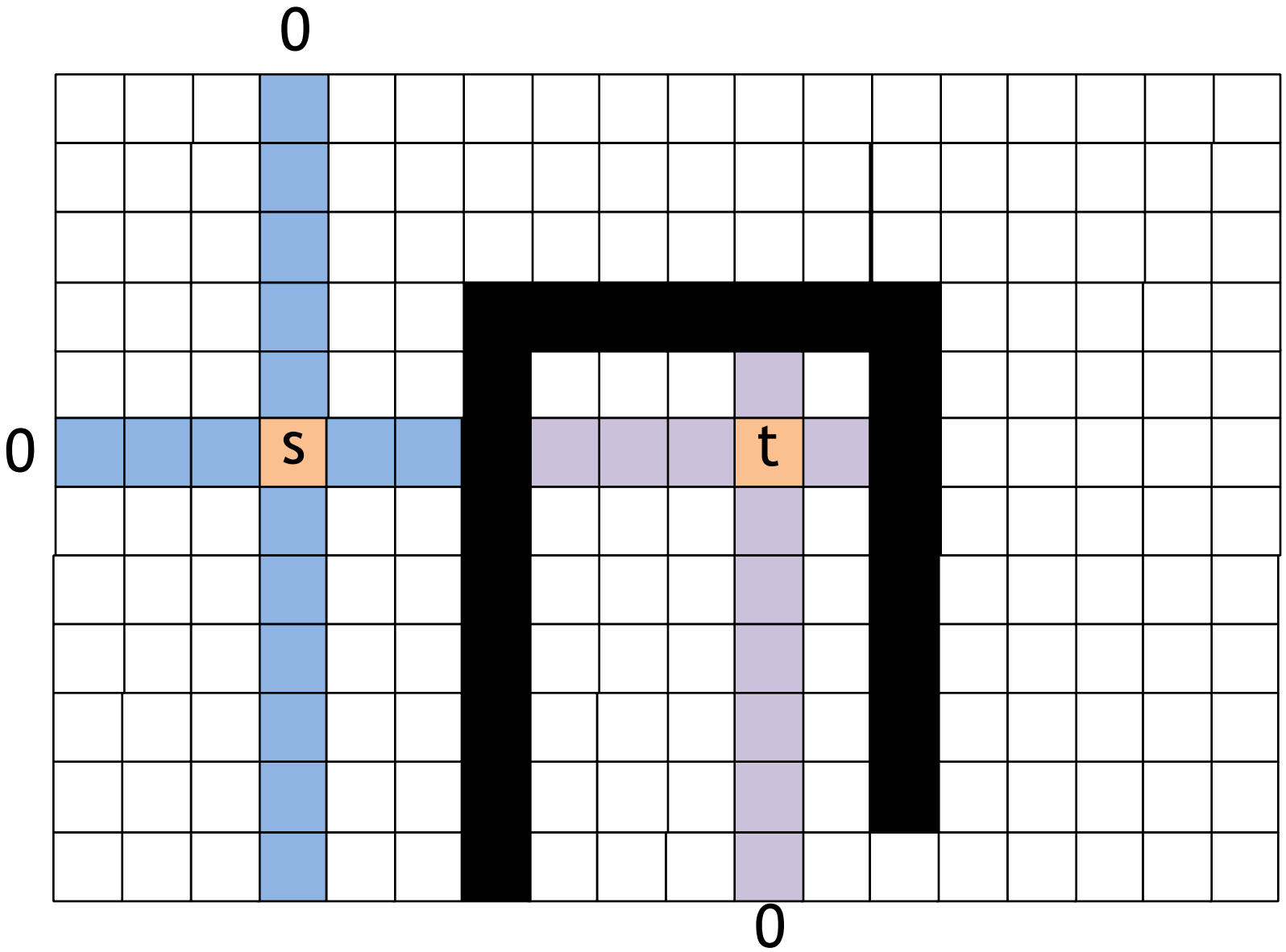
Sink Line Probe (Level 0)



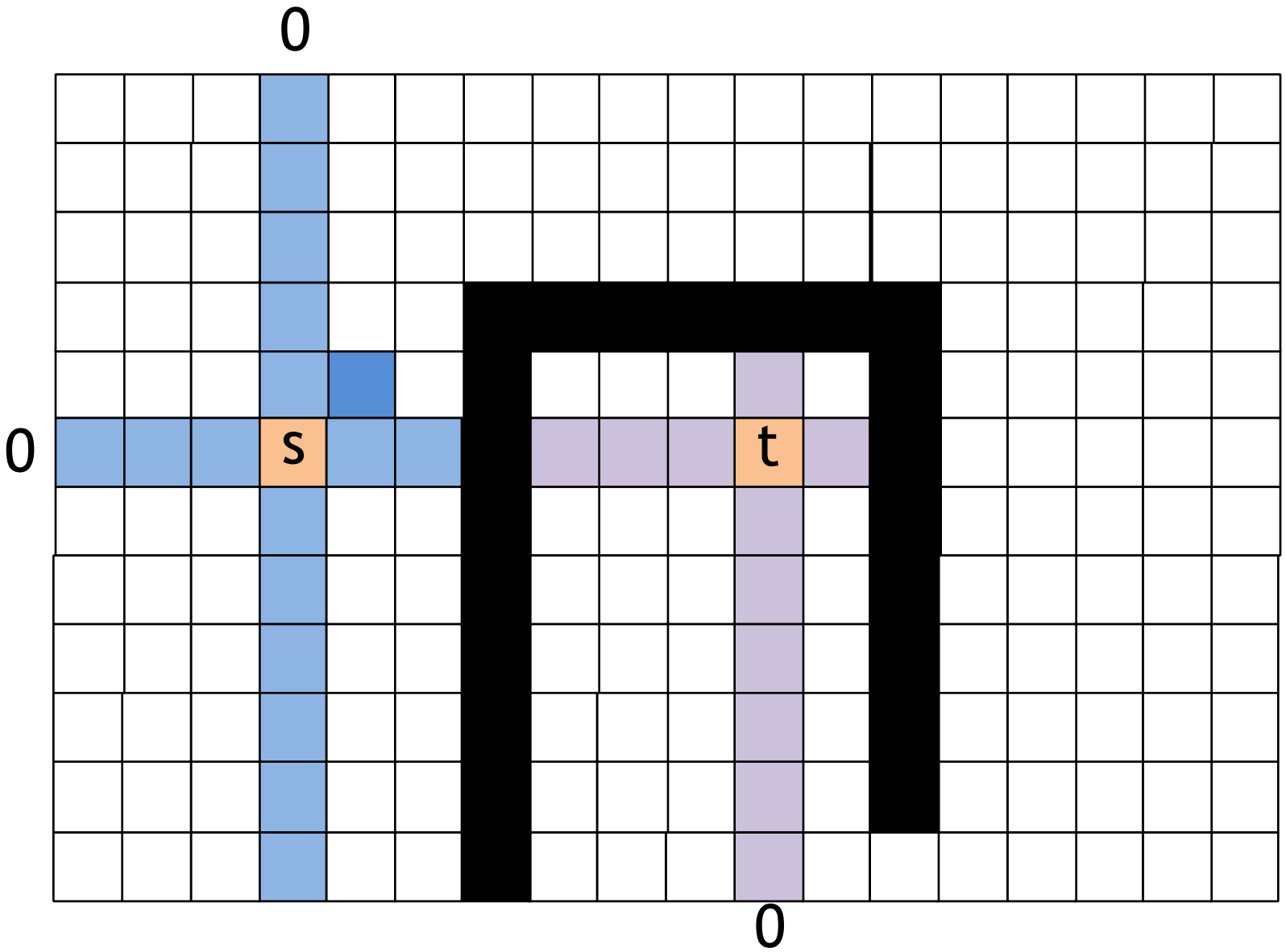
Sink Line Probe (Level 0)



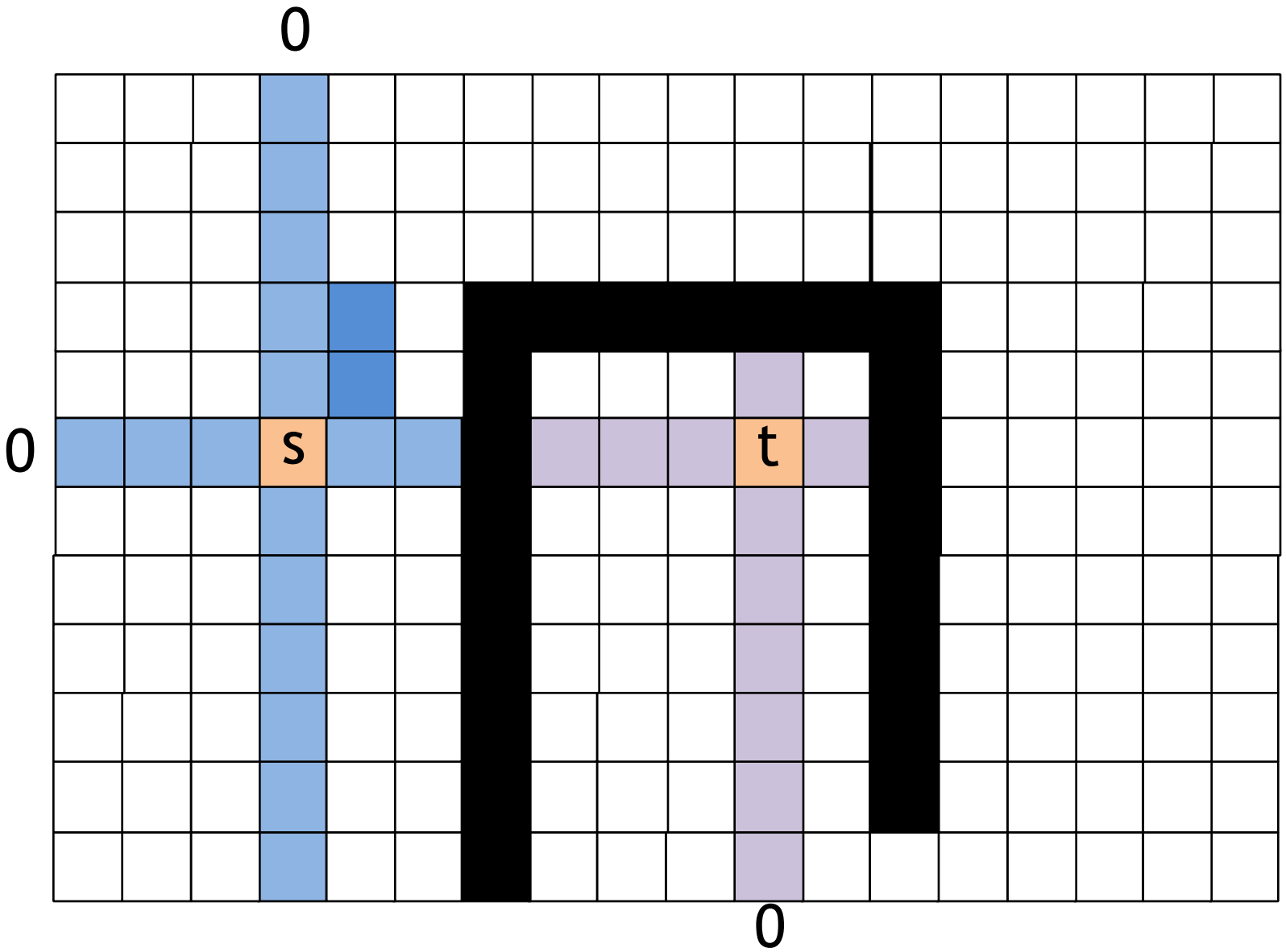
Source Line Probe (Level 1)



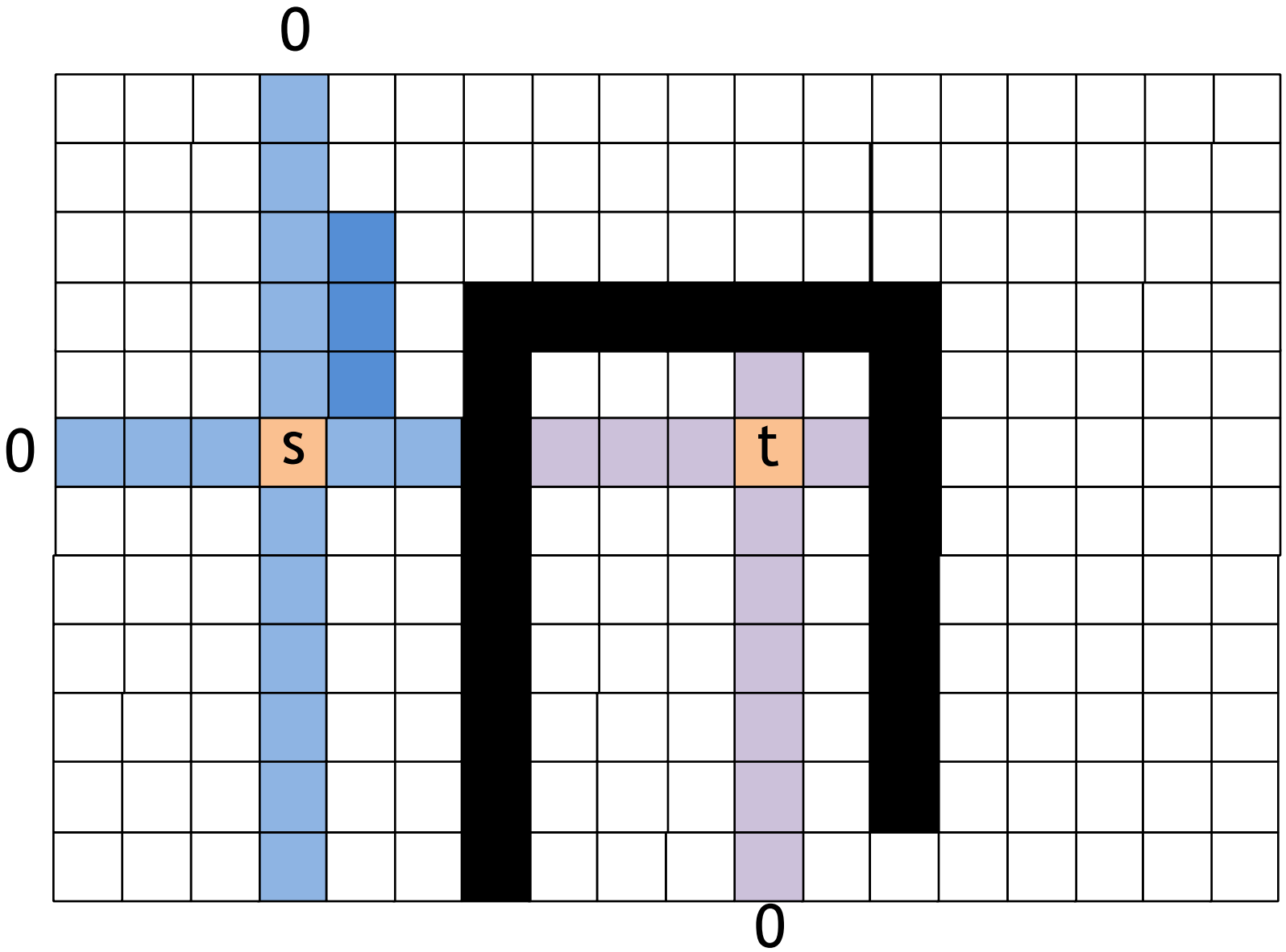
Source Line Probe (Level 1)



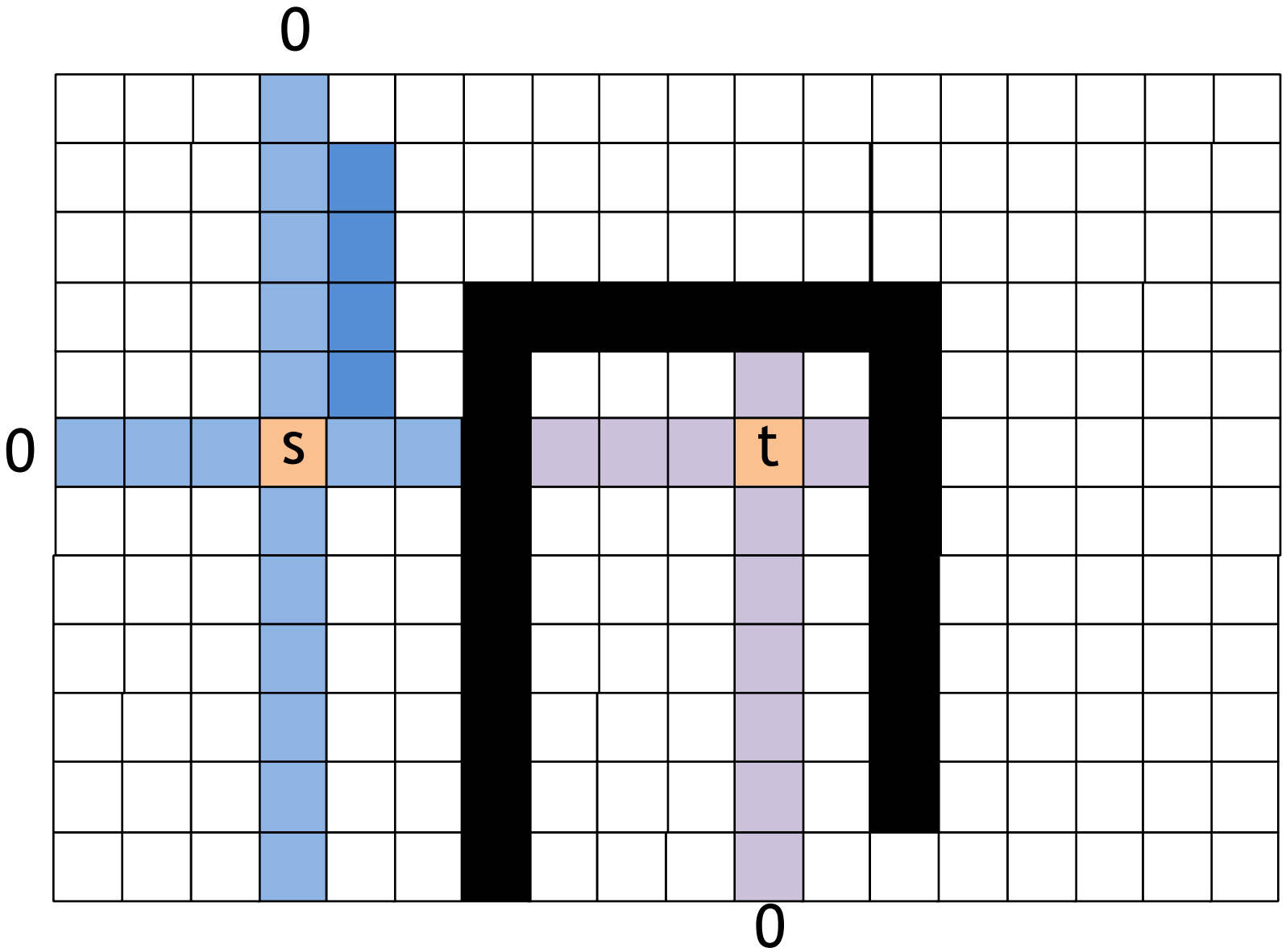
Source Line Probe (Level 1)



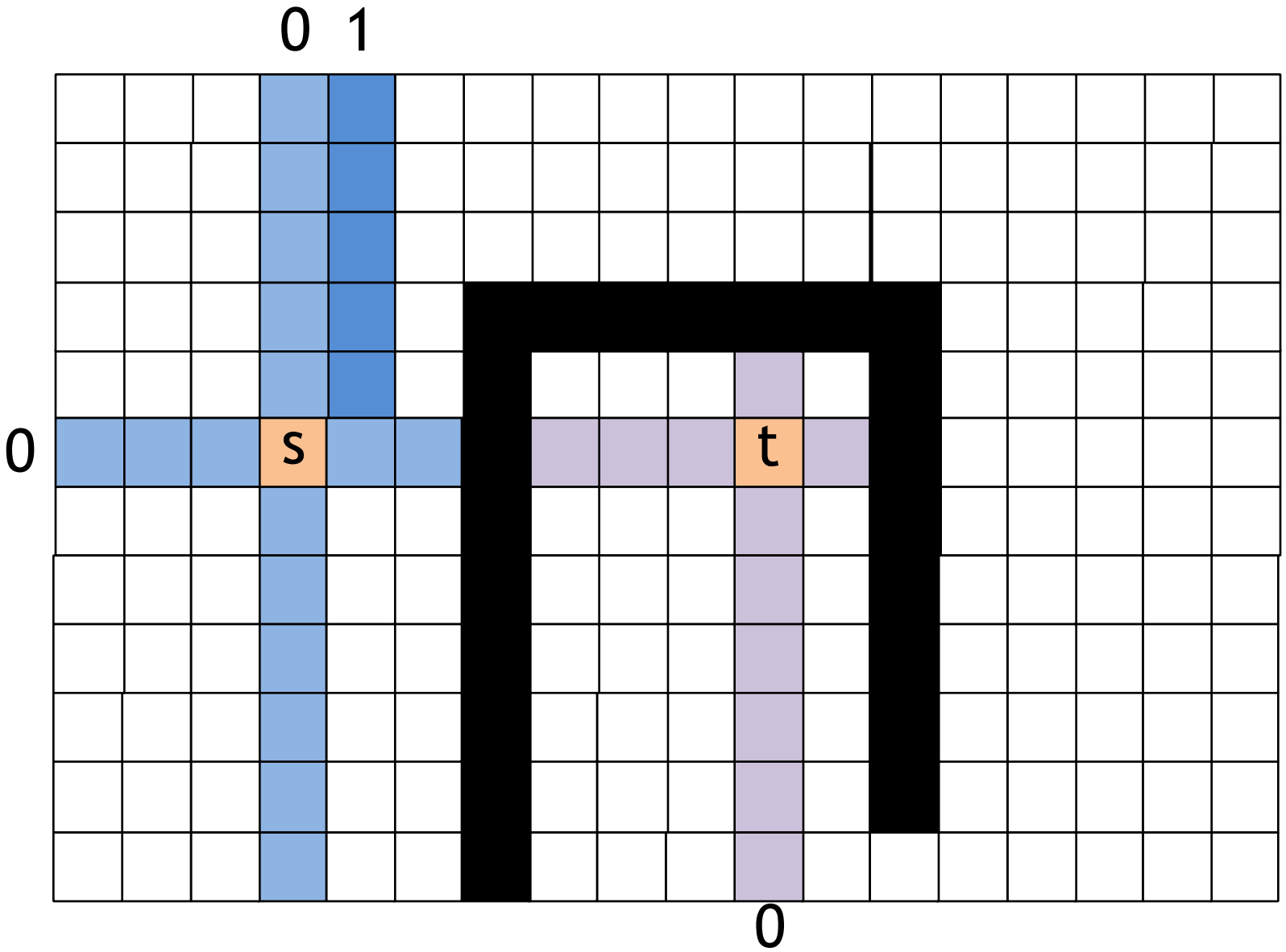
Source Line Probe (Level 1)



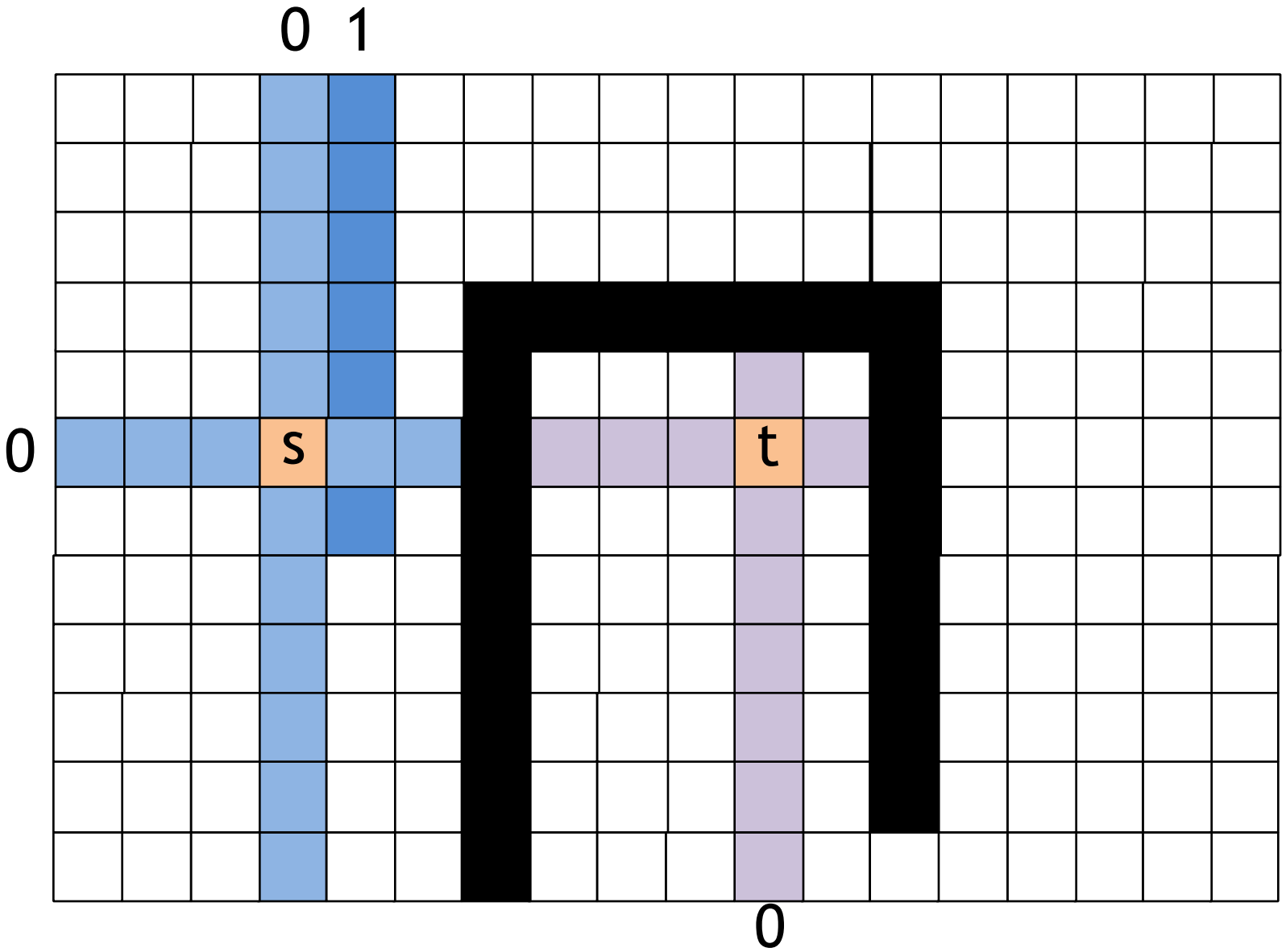
Source Line Probe (Level 1)



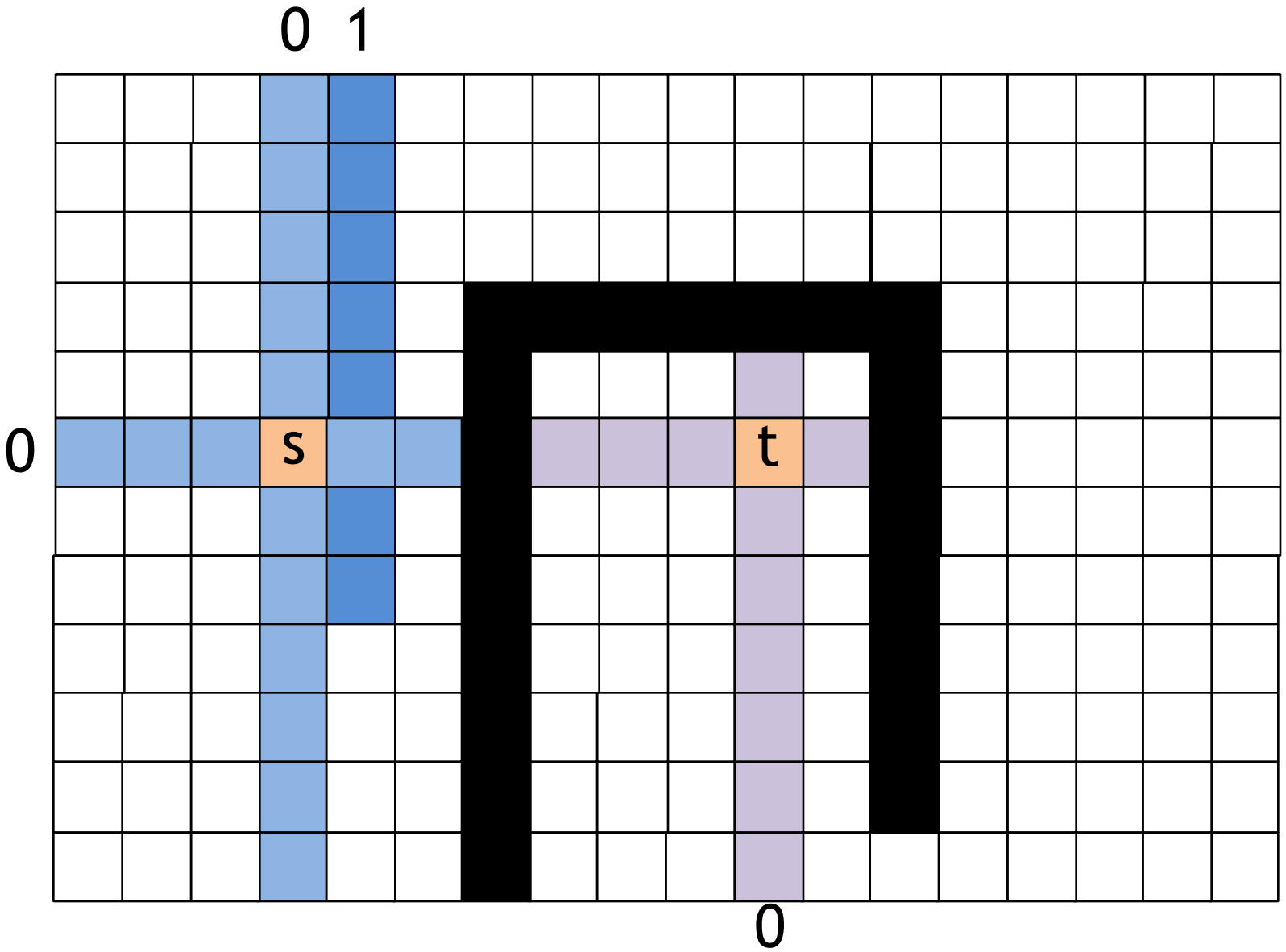
Source Line Probe (Level 1)



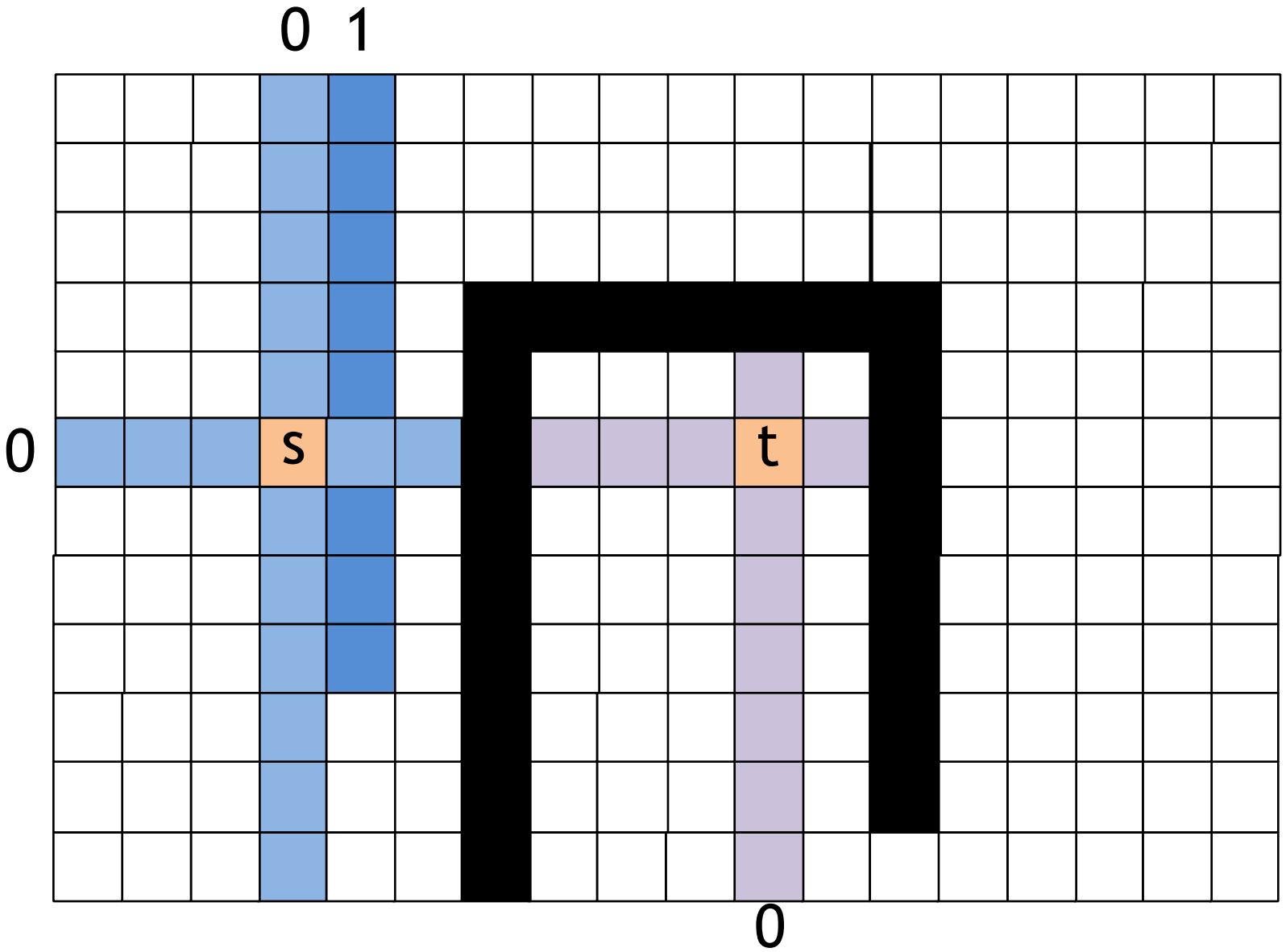
Source Line Probe (Level 1)



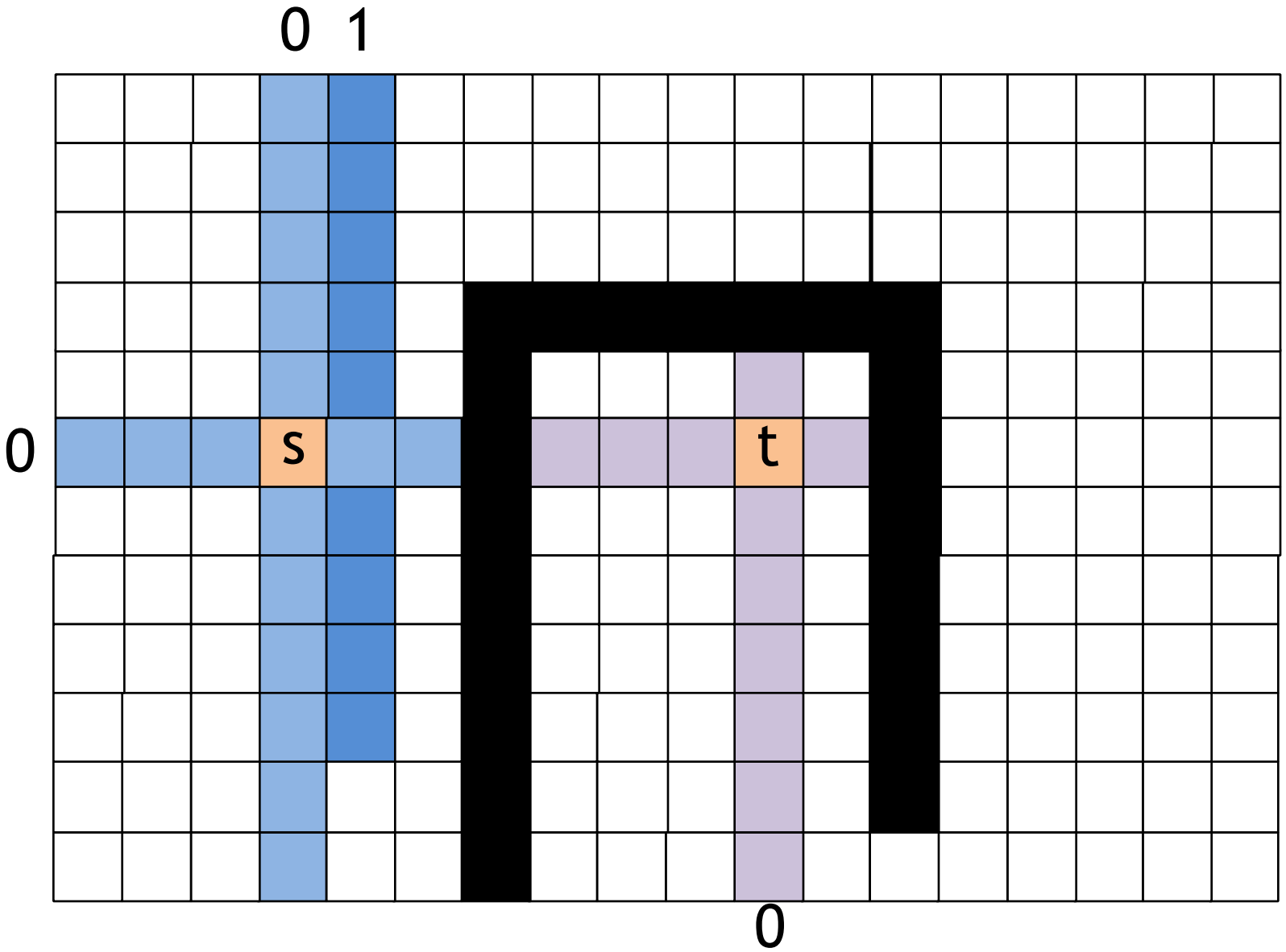
Source Line Probe (Level 1)



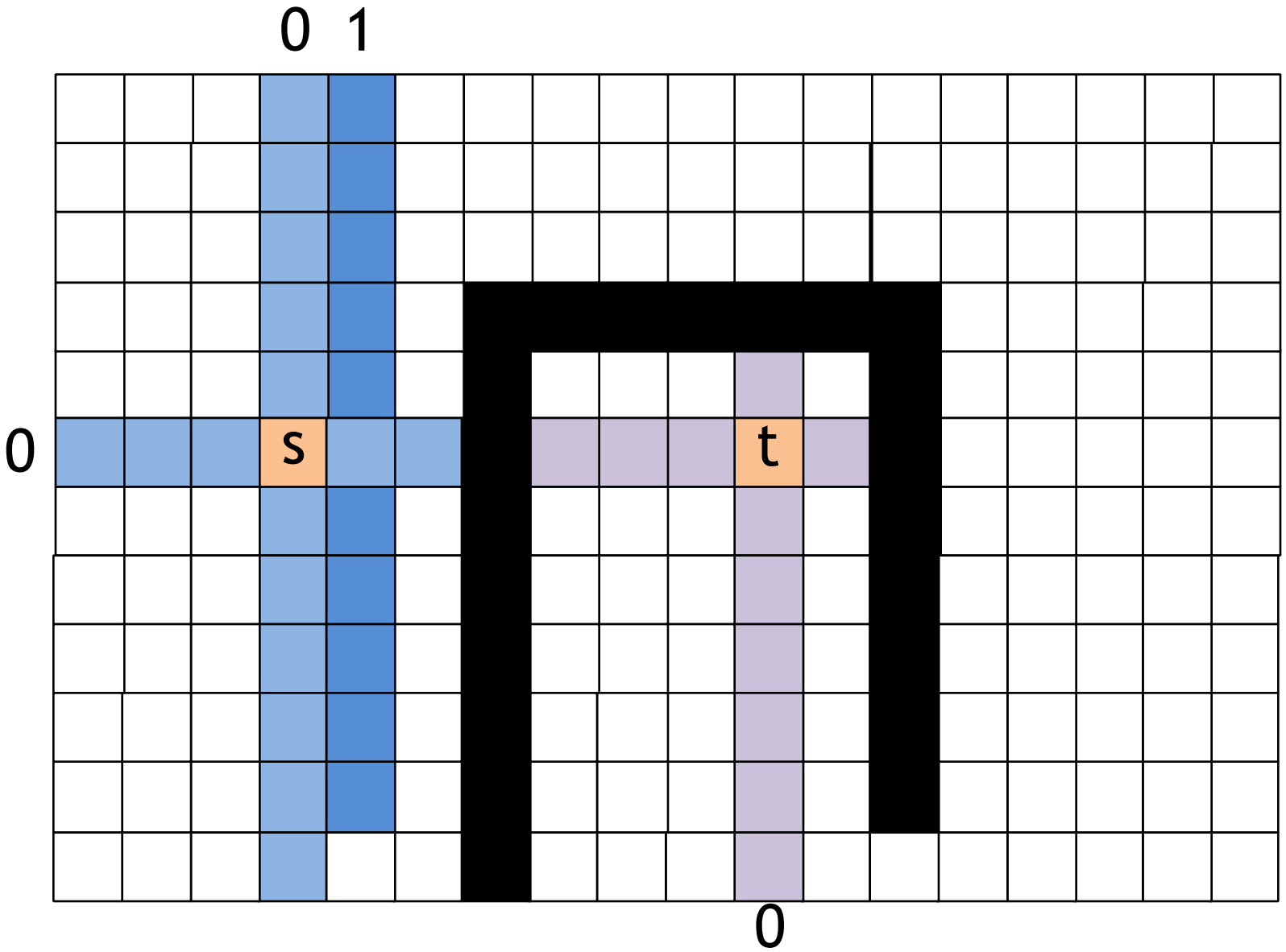
Source Line Probe (Level 1)



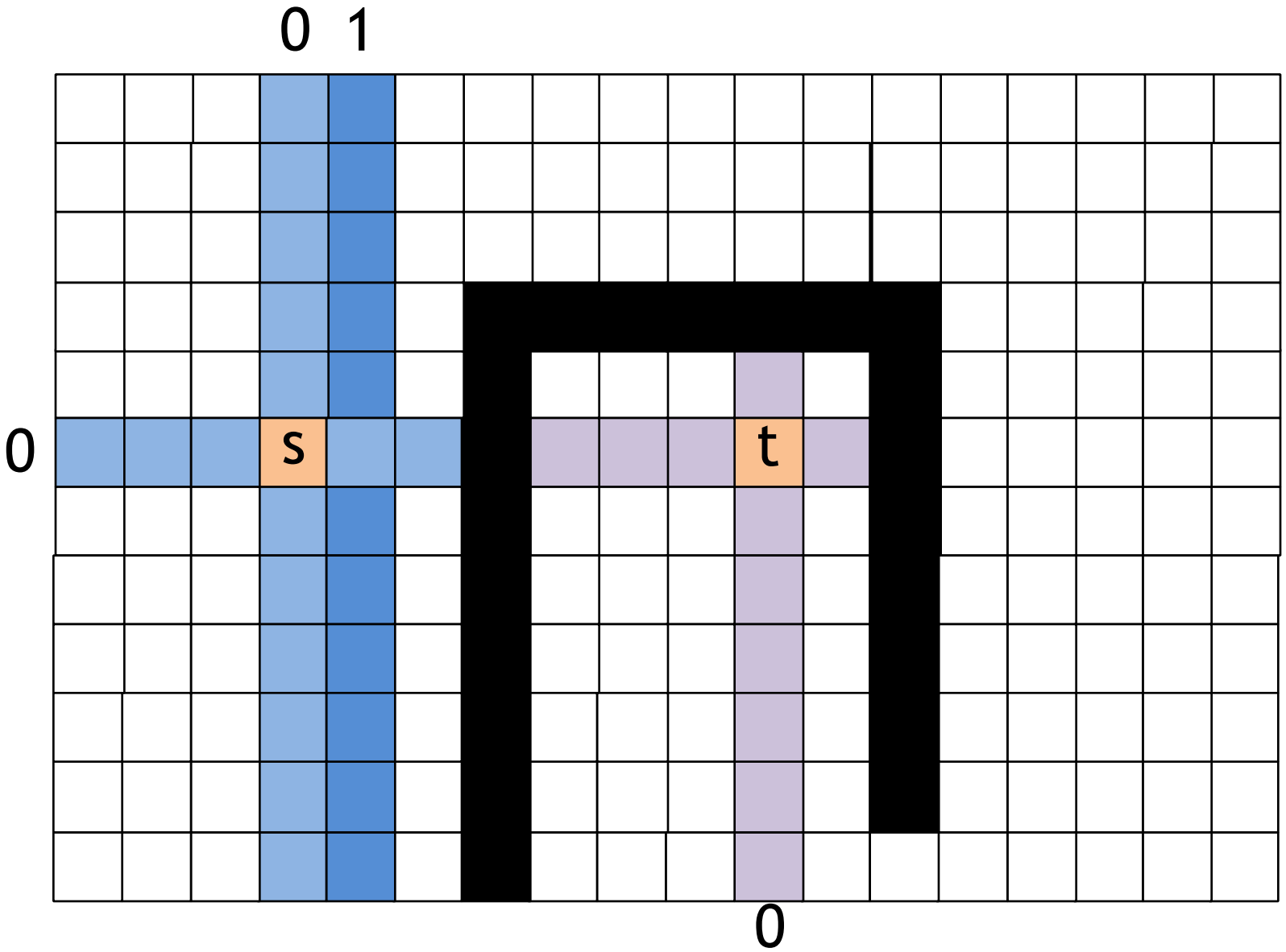
Source Line Probe (Level 1)



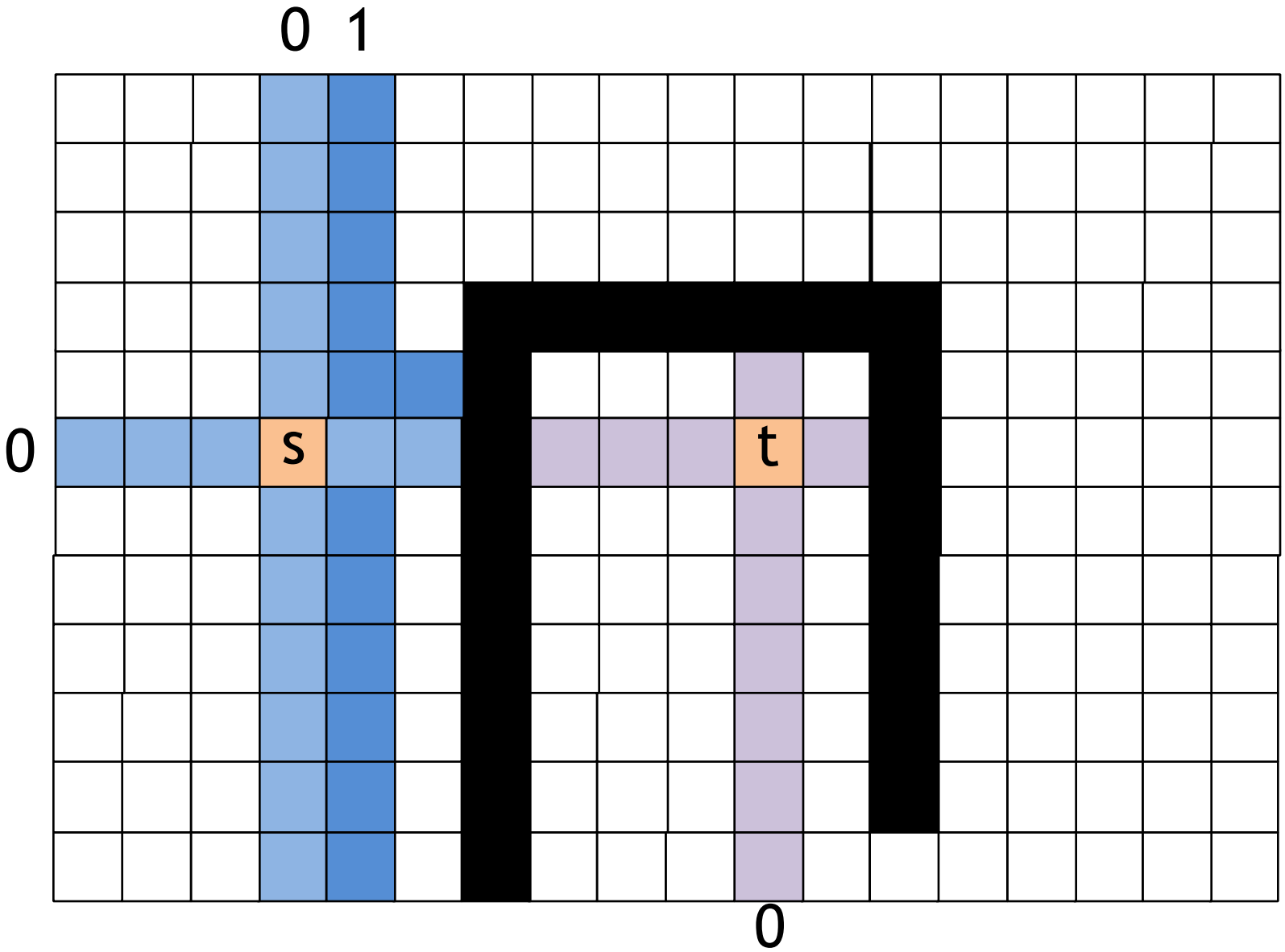
Source Line Probe (Level 1)



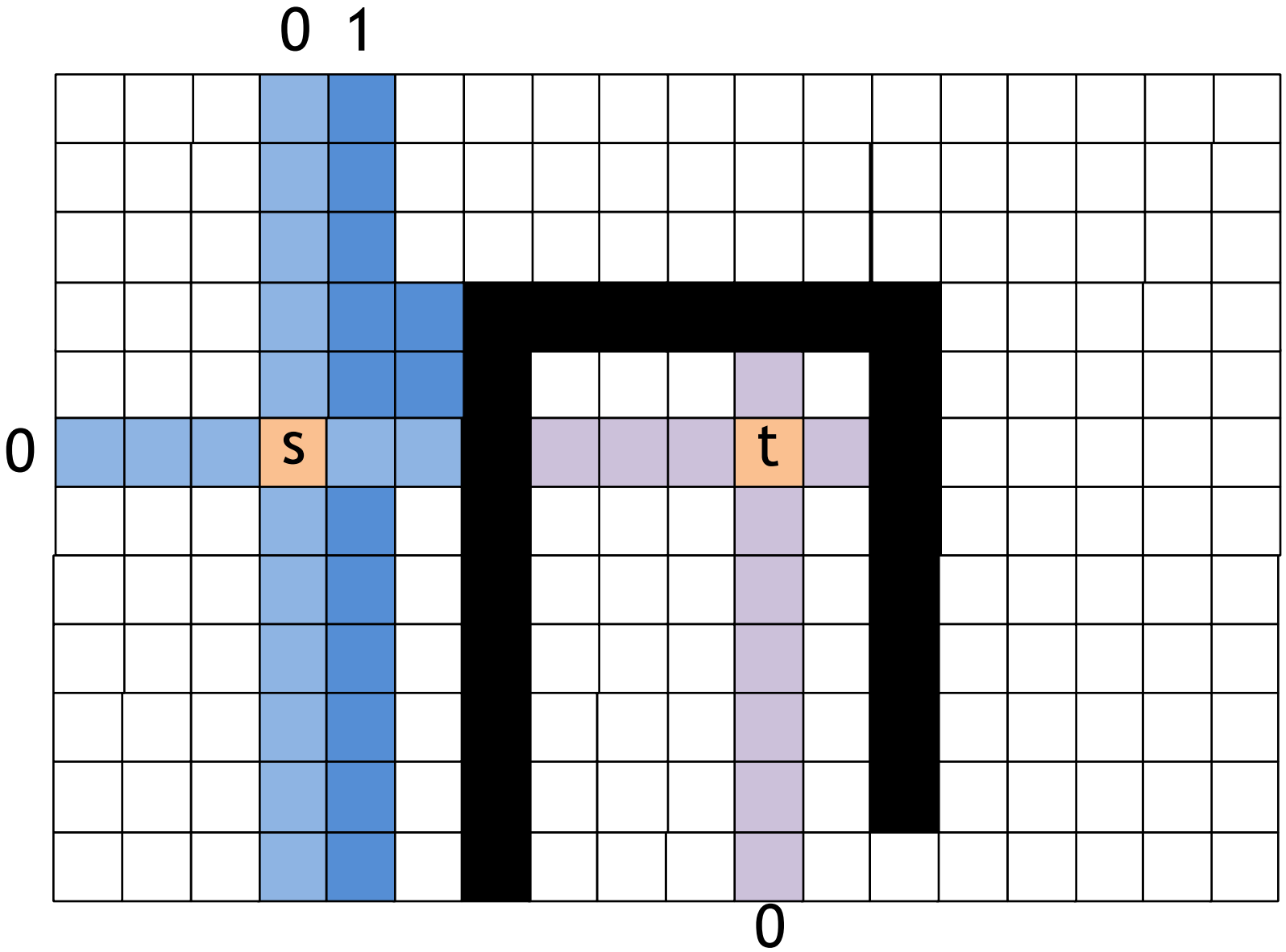
Source Line Probe (Level 1)



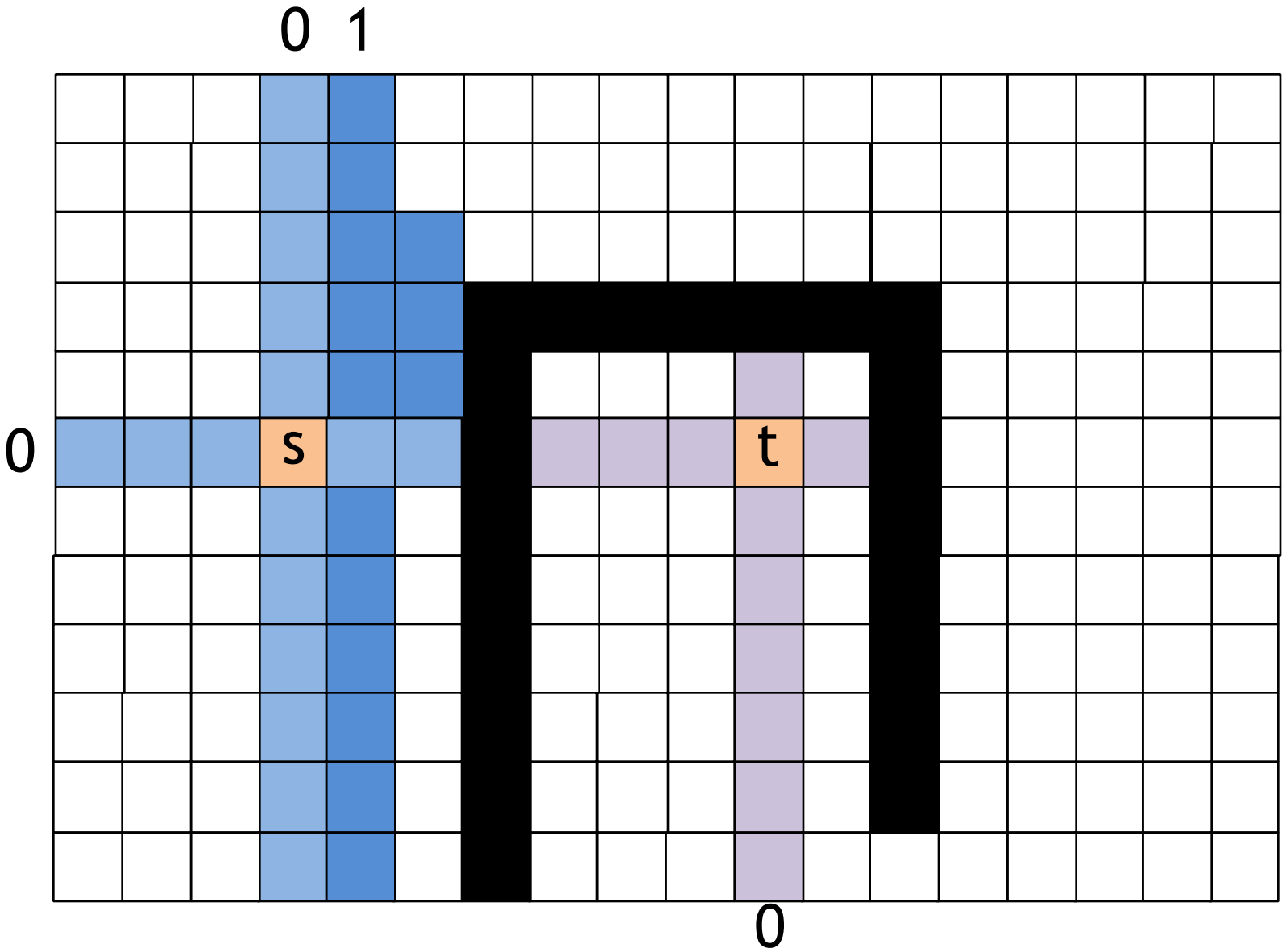
Source Line Probe (Level 1)



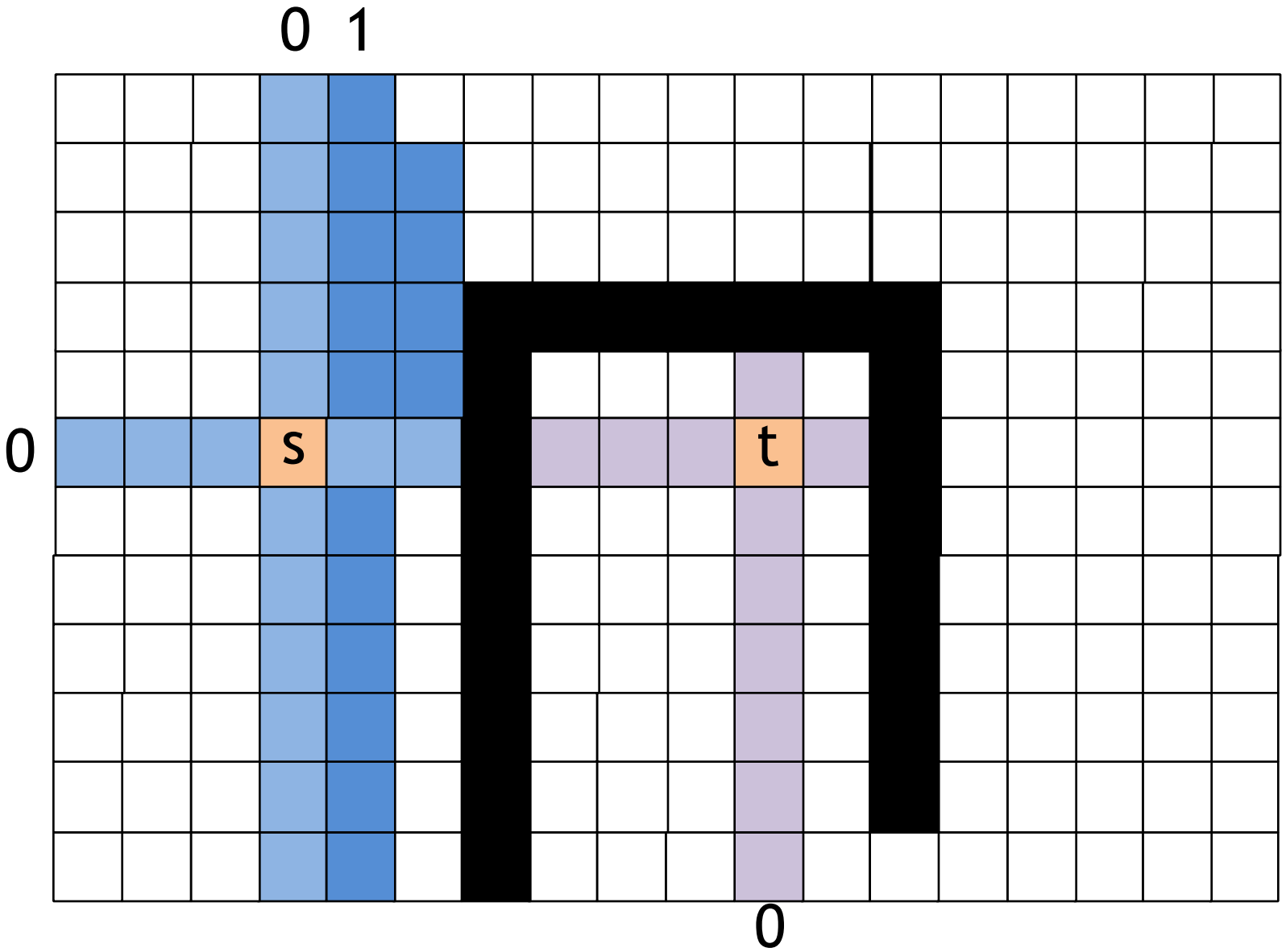
Source Line Probe (Level 1)



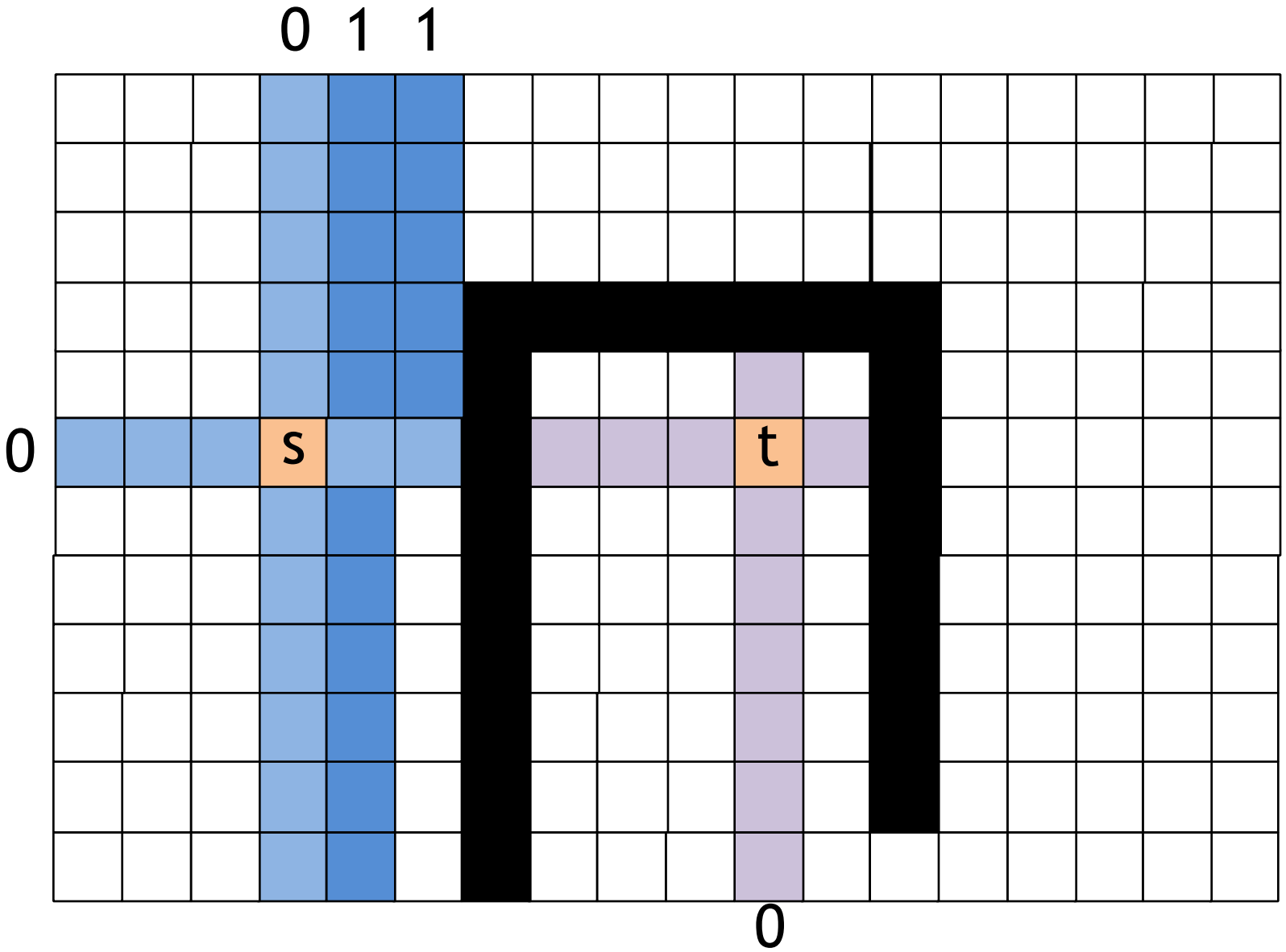
Source Line Probe (Level 1)



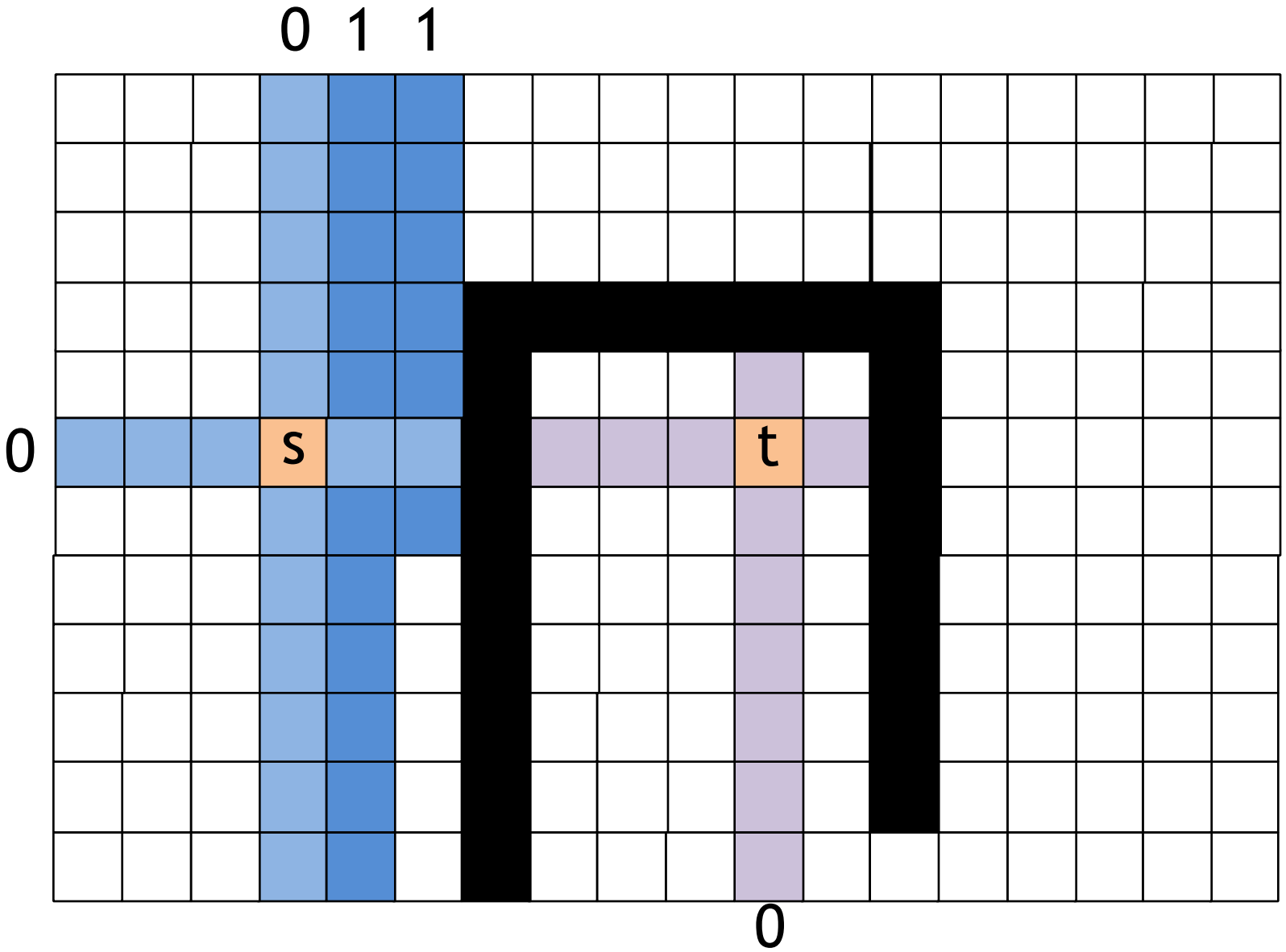
Source Line Probe (Level 1)



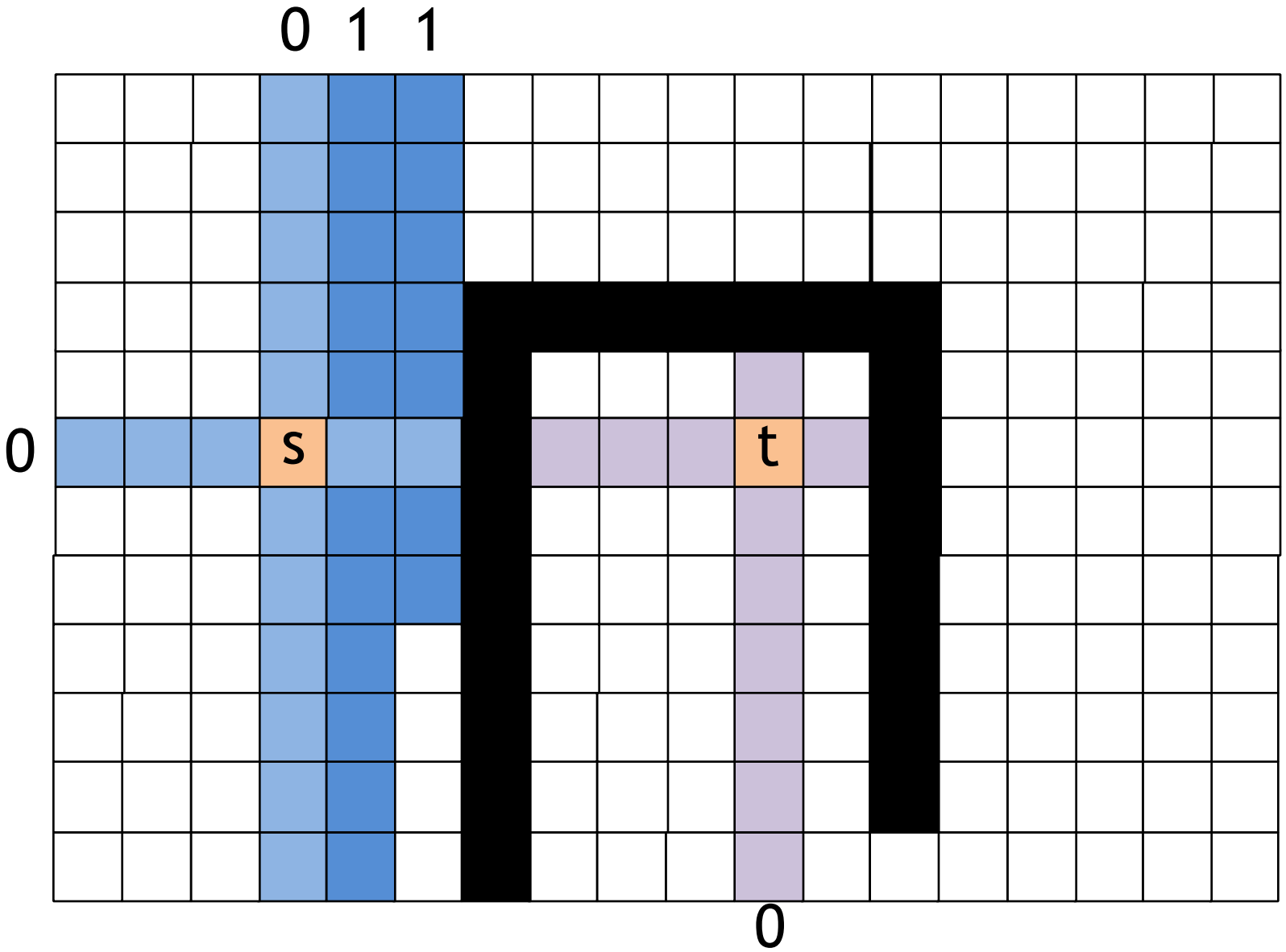
Source Line Probe (Level 1)



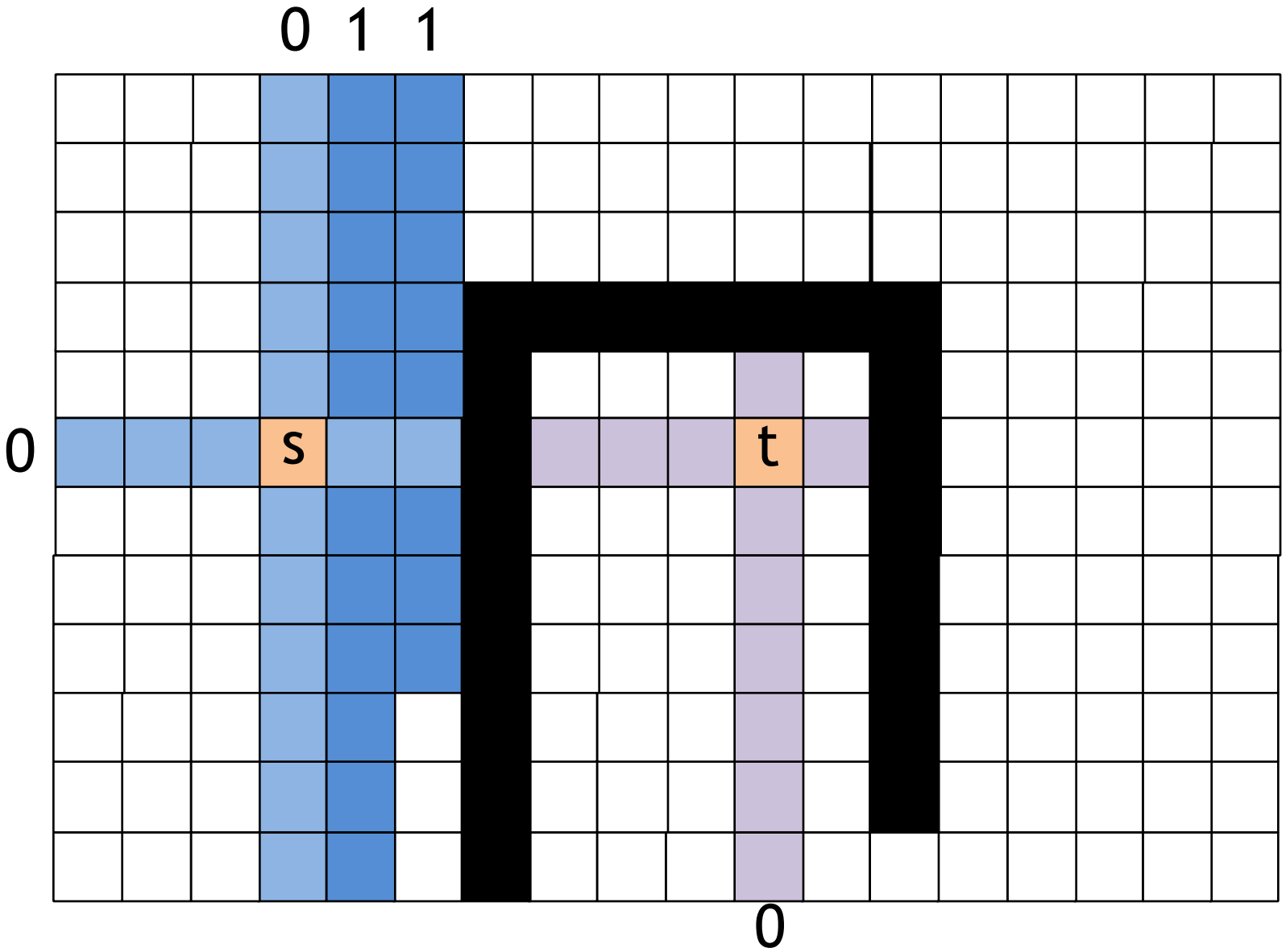
Source Line Probe (Level 1)



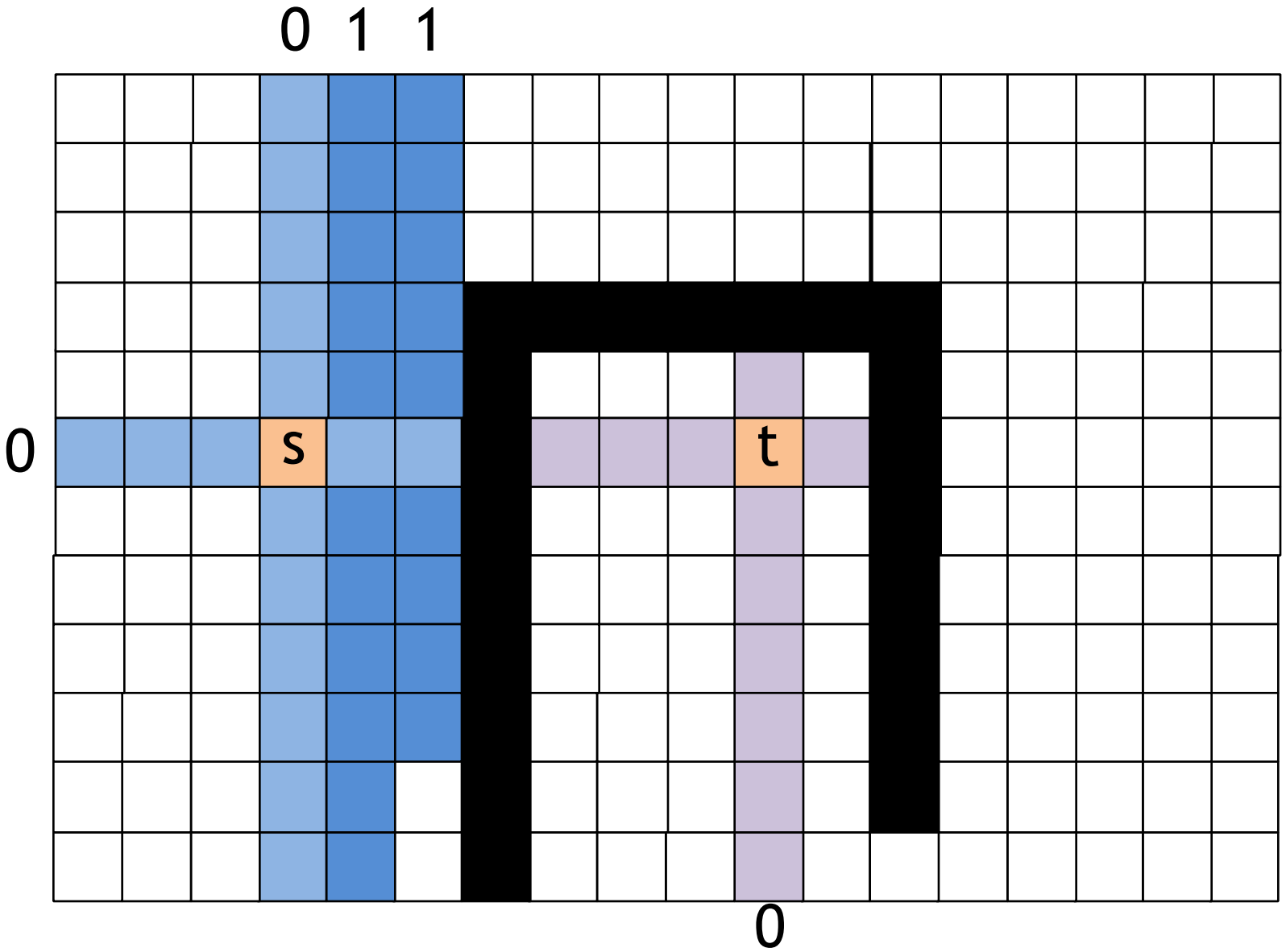
Source Line Probe (Level 1)



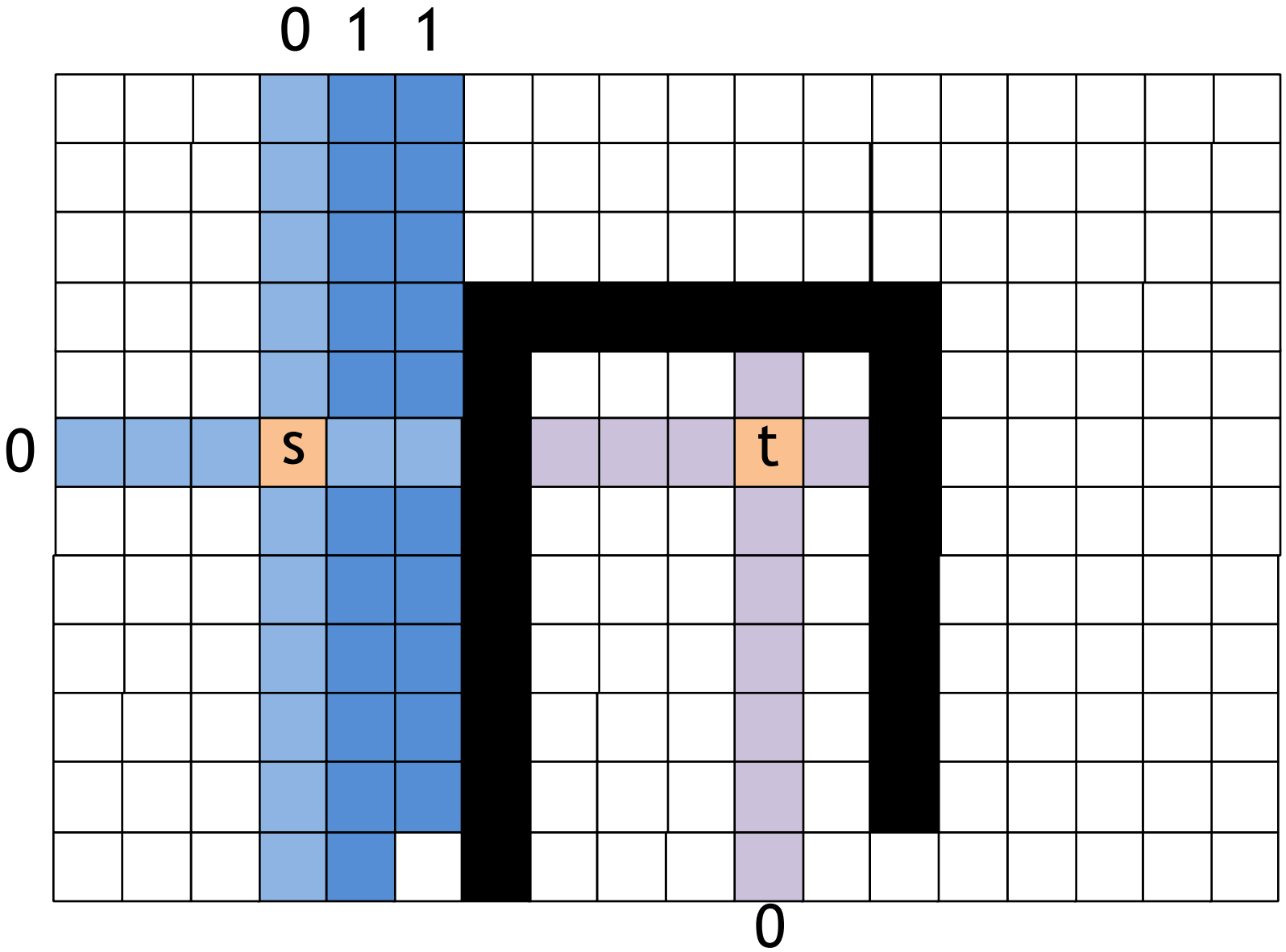
Source Line Probe (Level 1)



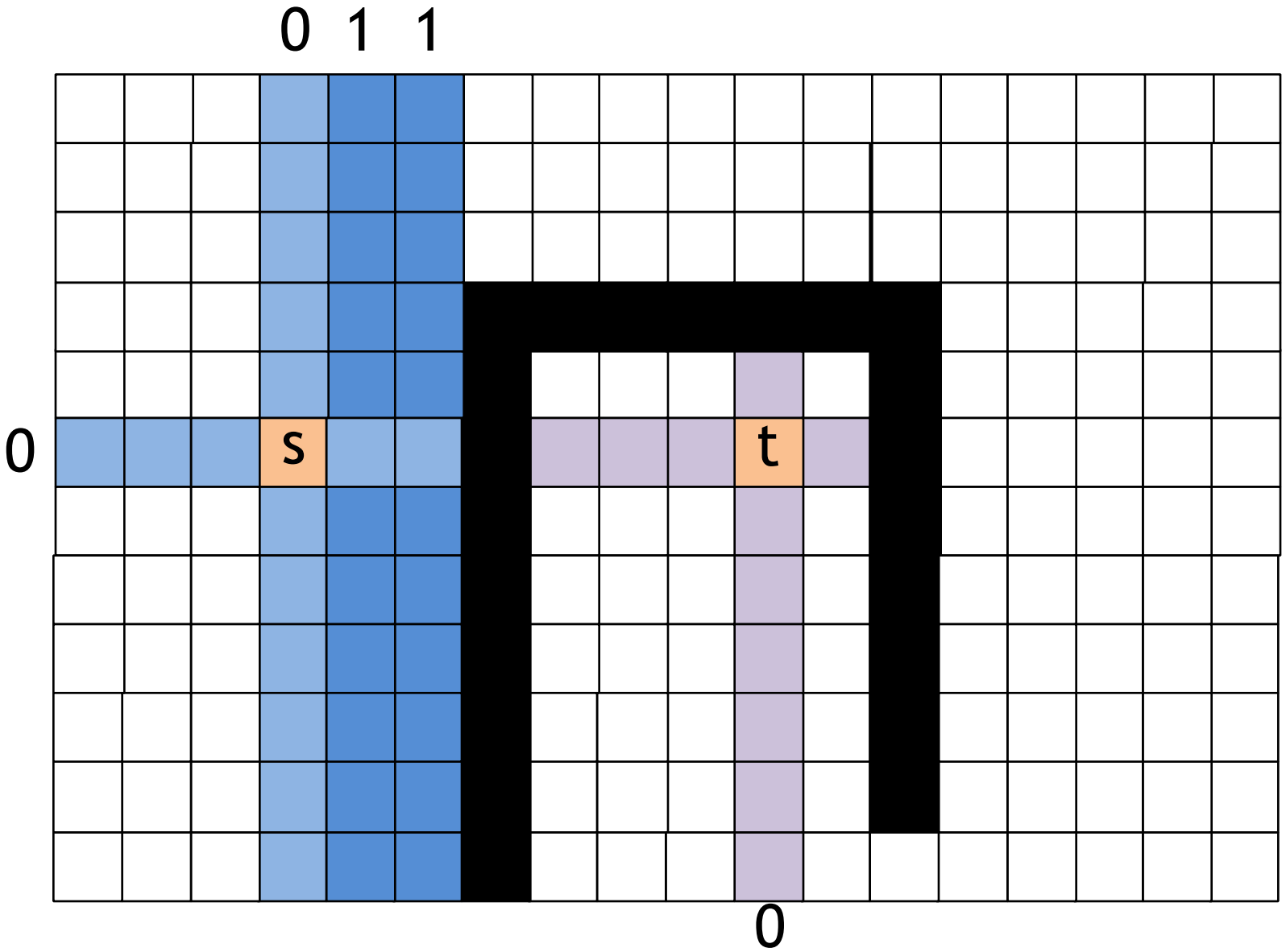
Source Line Probe (Level 1)



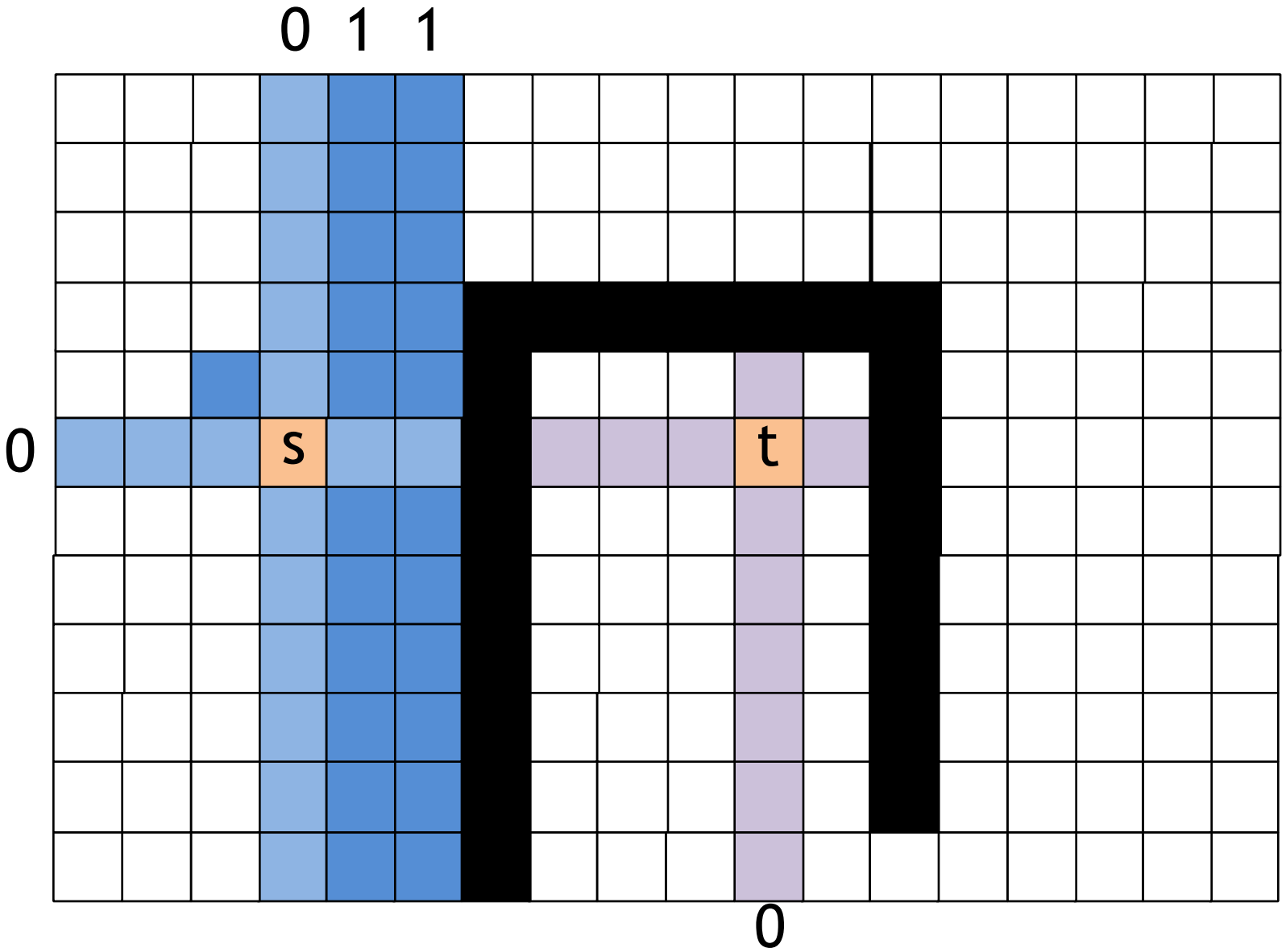
Source Line Probe (Level 1)



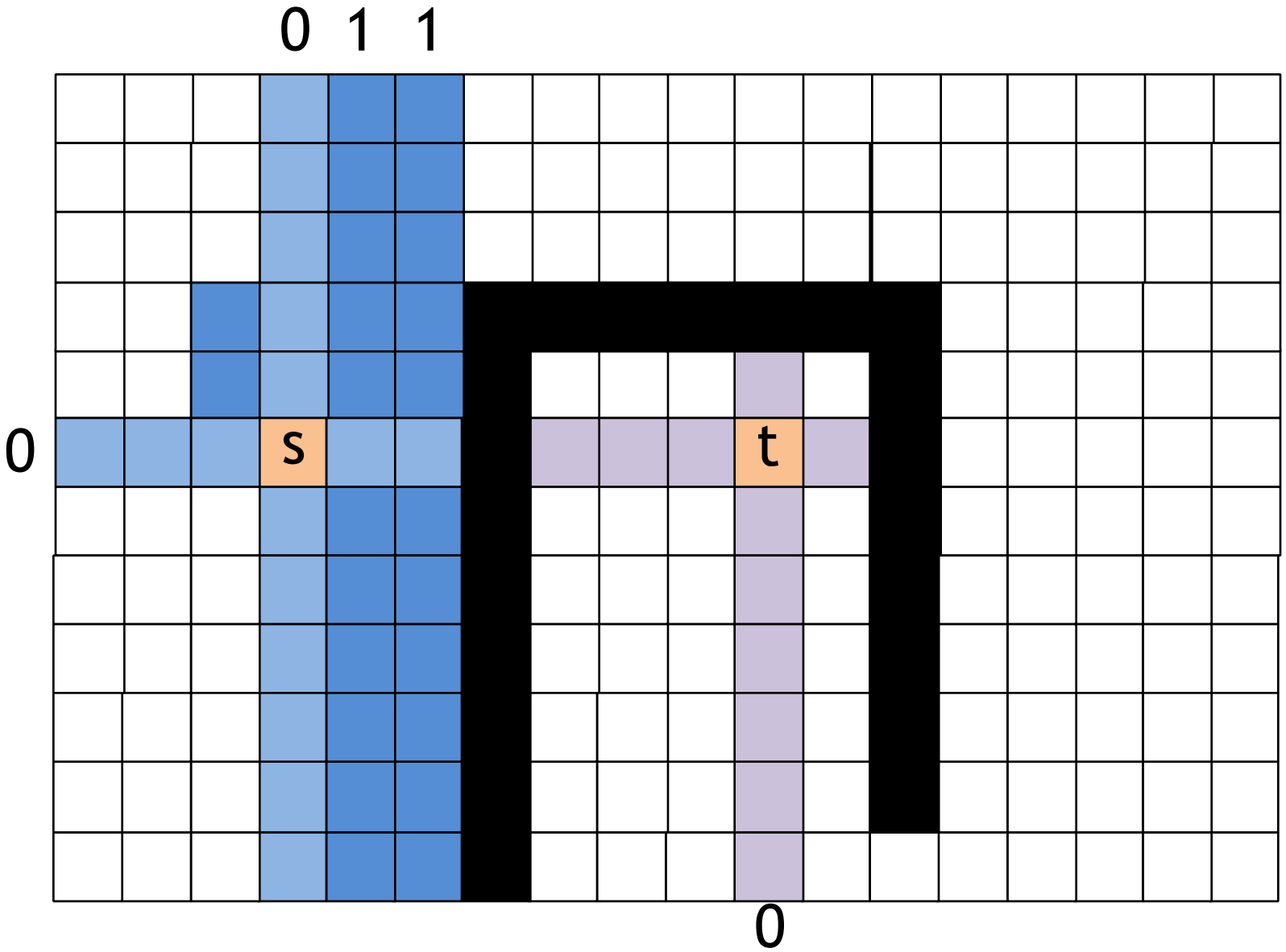
Source Line Probe (Level 1)



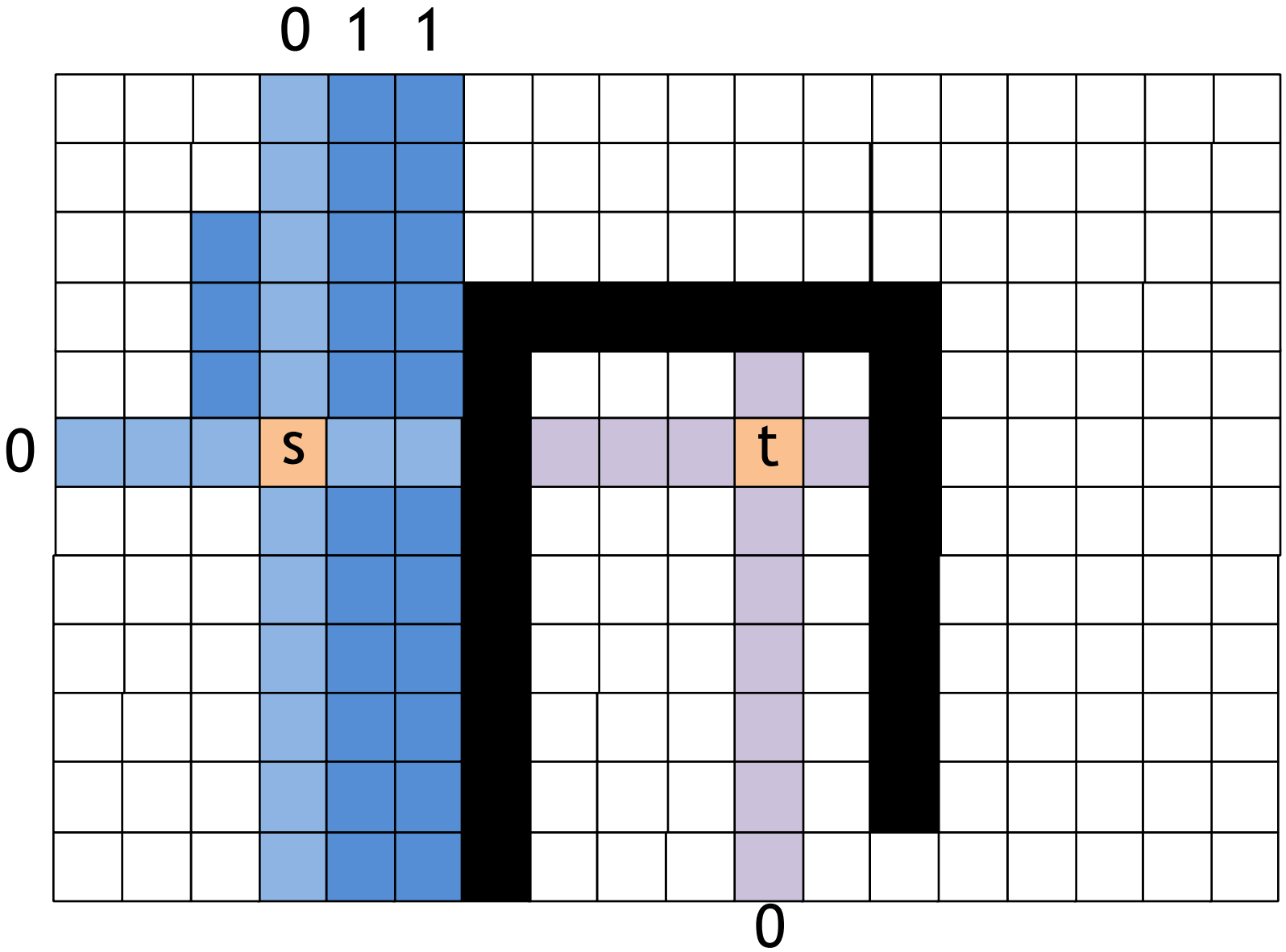
Source Line Probe (Level 1)



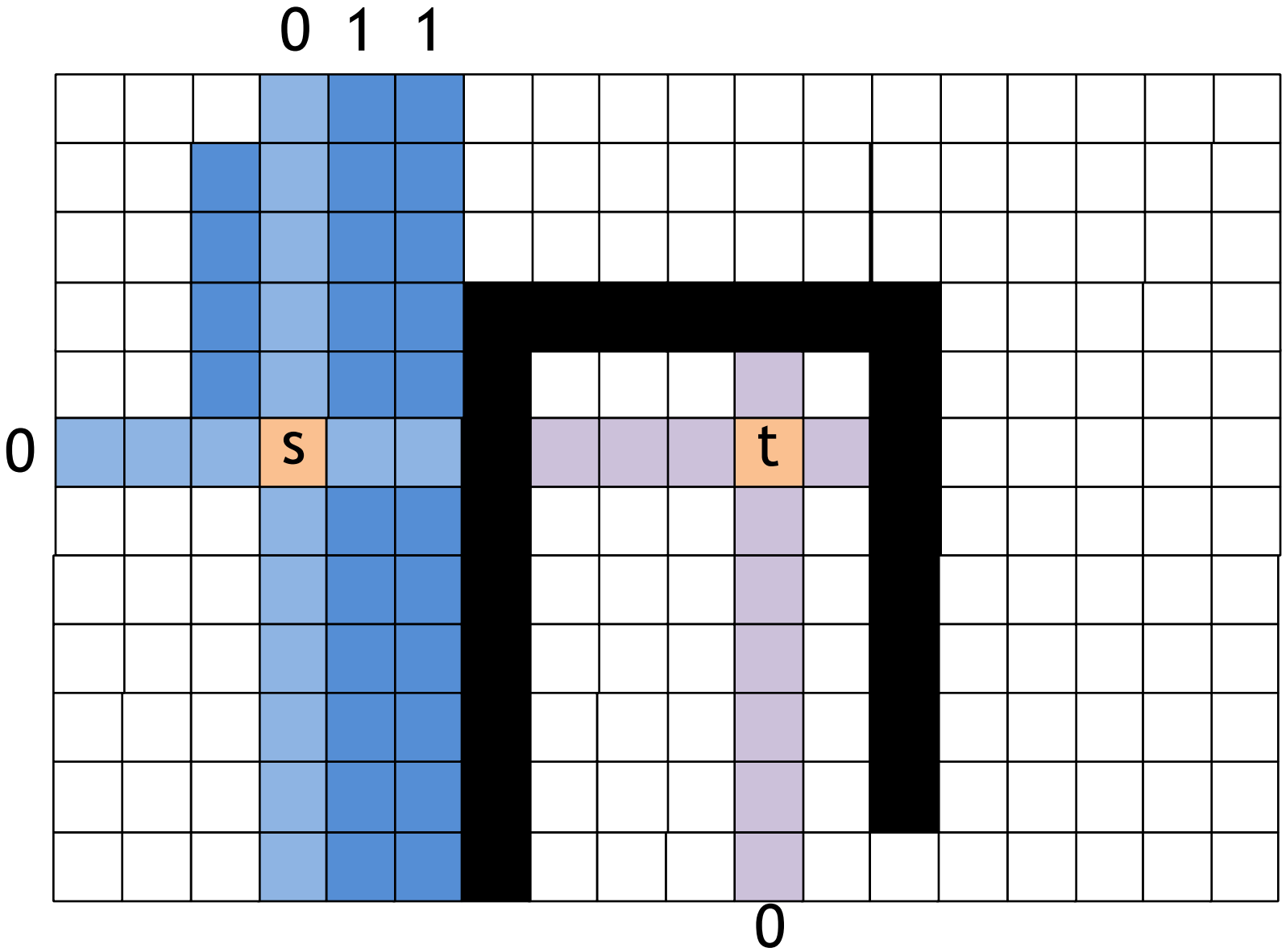
Source Line Probe (Level 1)



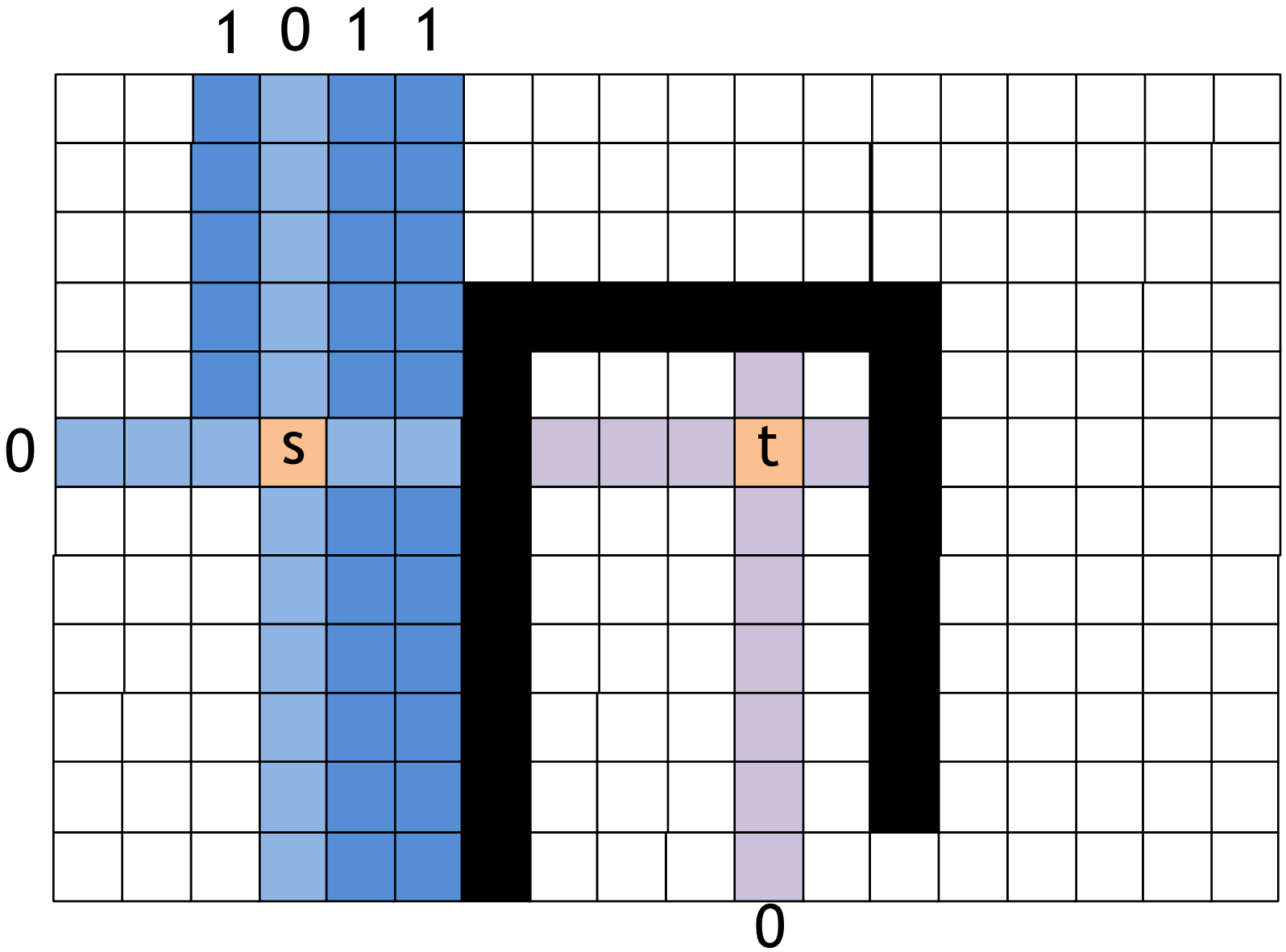
Source Line Probe (Level 1)



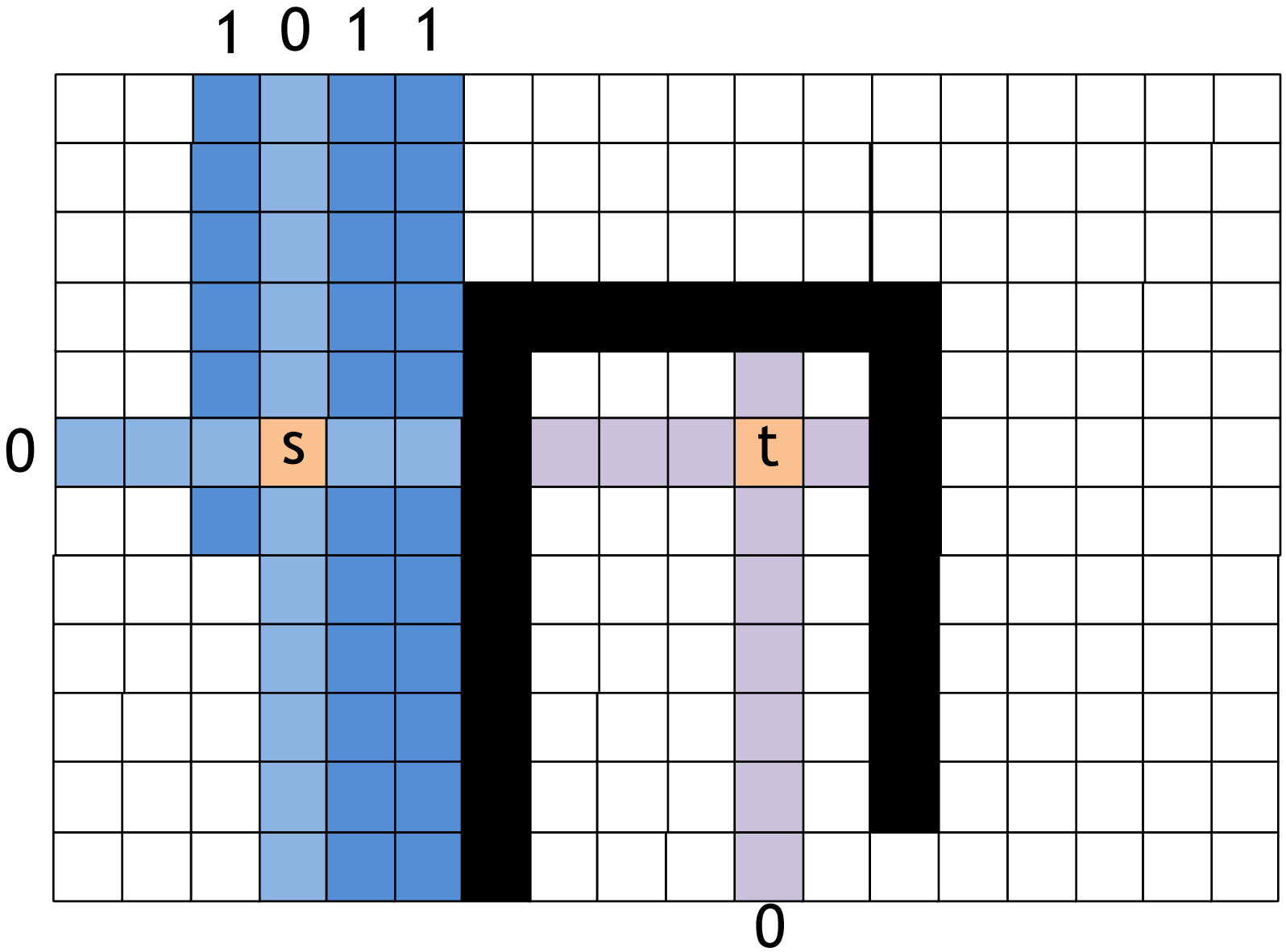
Source Line Probe (Level 1)



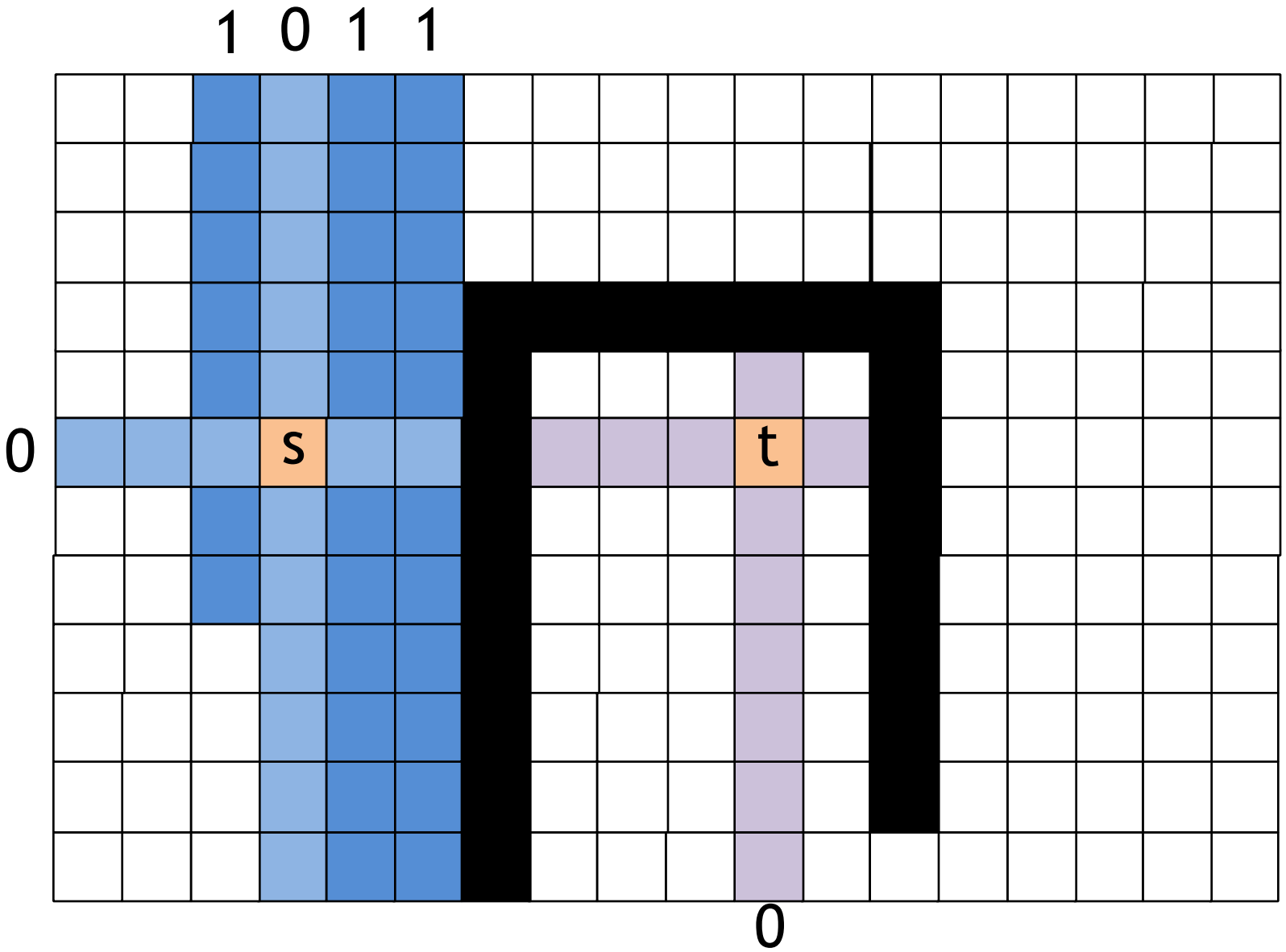
Source Line Probe (Level 1)



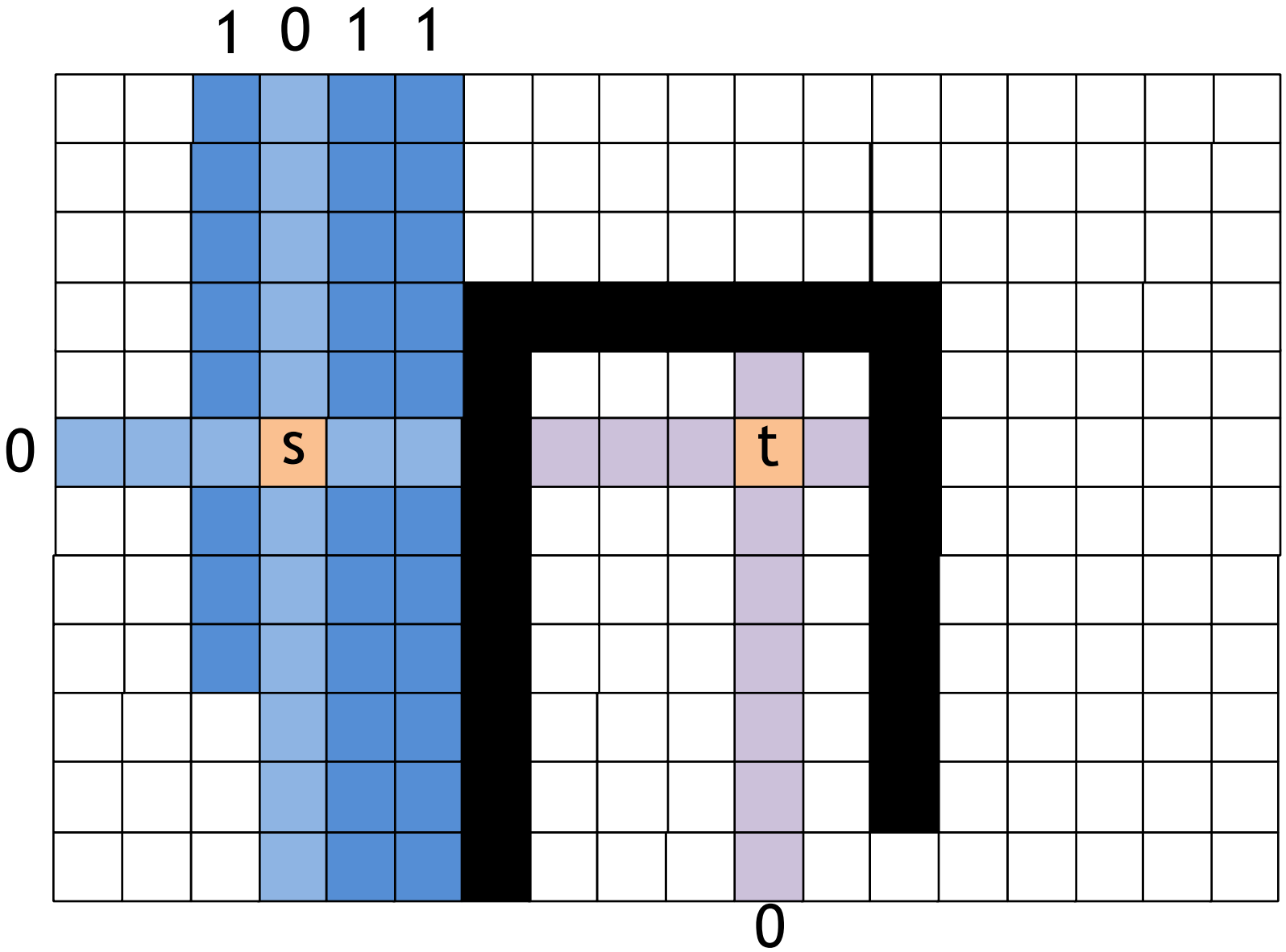
Source Line Probe (Level 1)



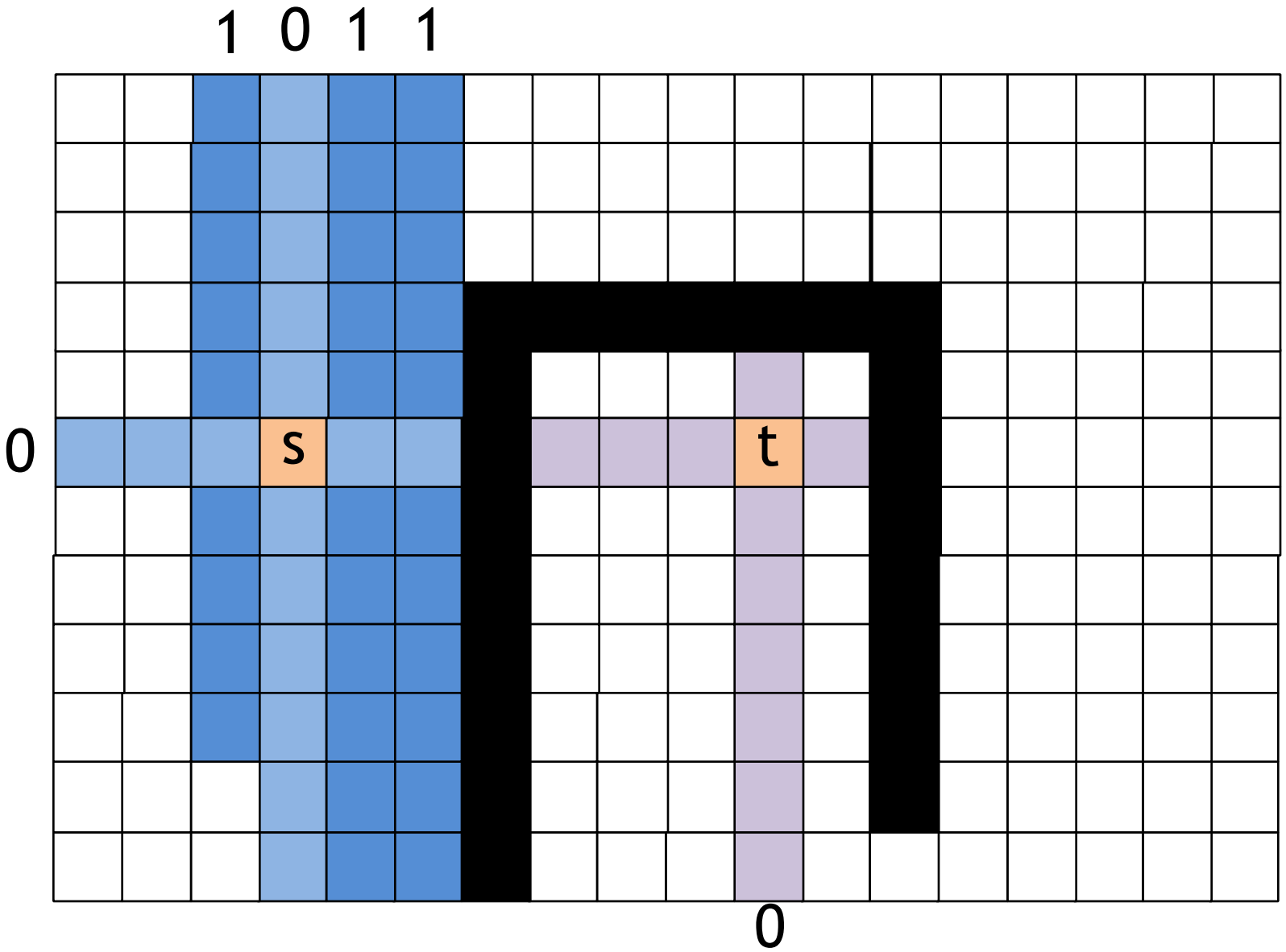
Source Line Probe (Level 1)



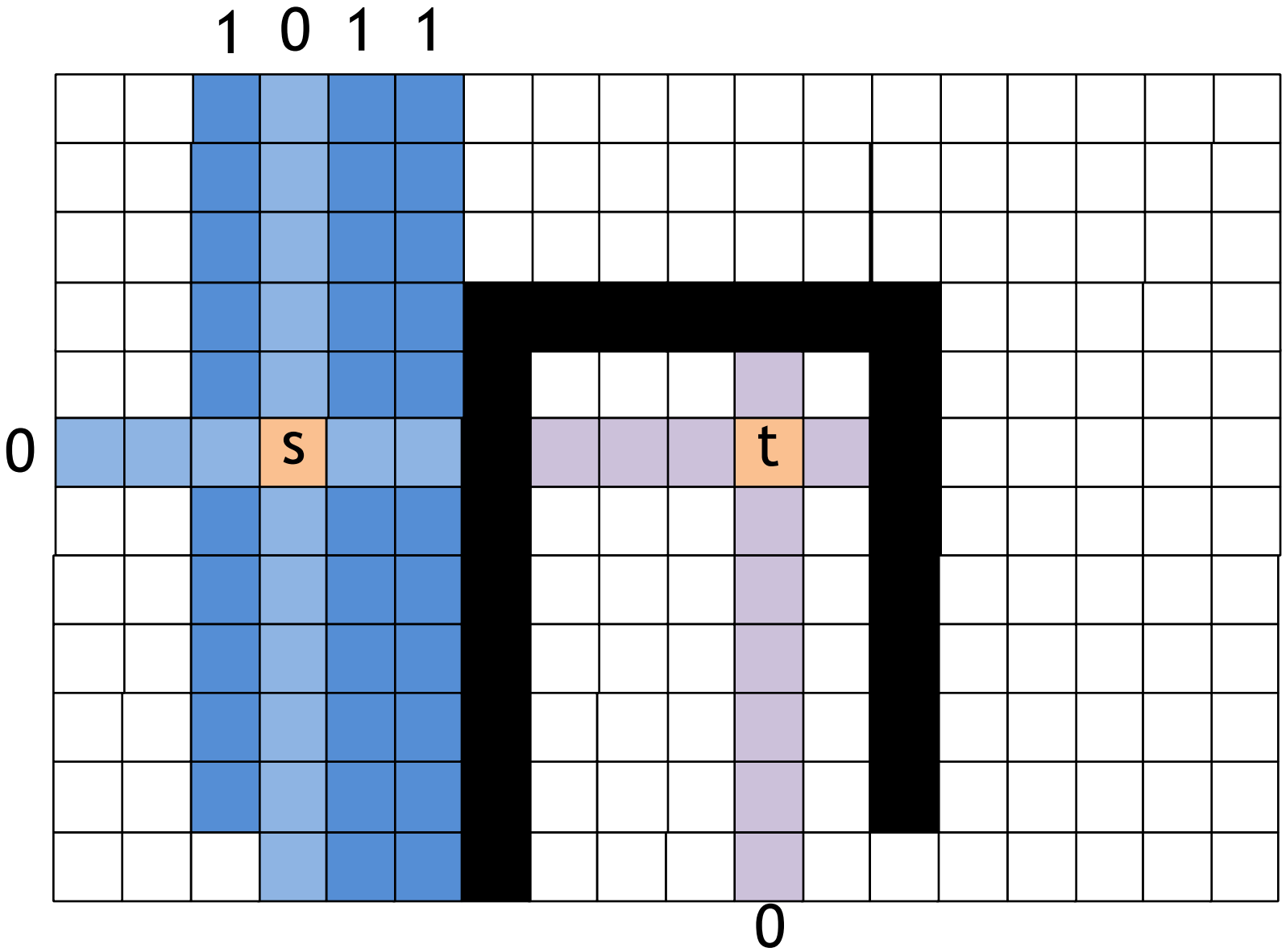
Source Line Probe (Level 1)



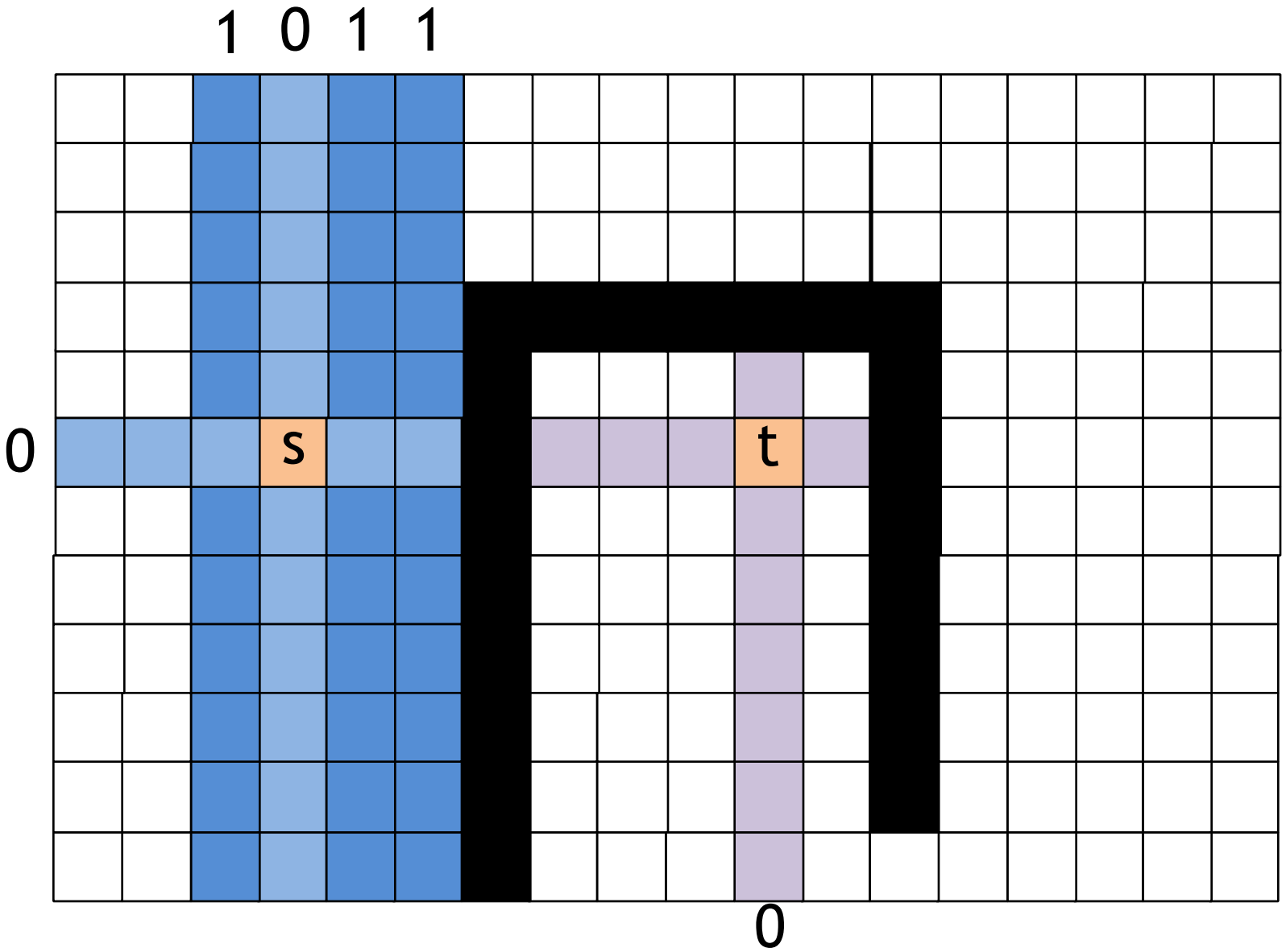
Source Line Probe (Level 1)



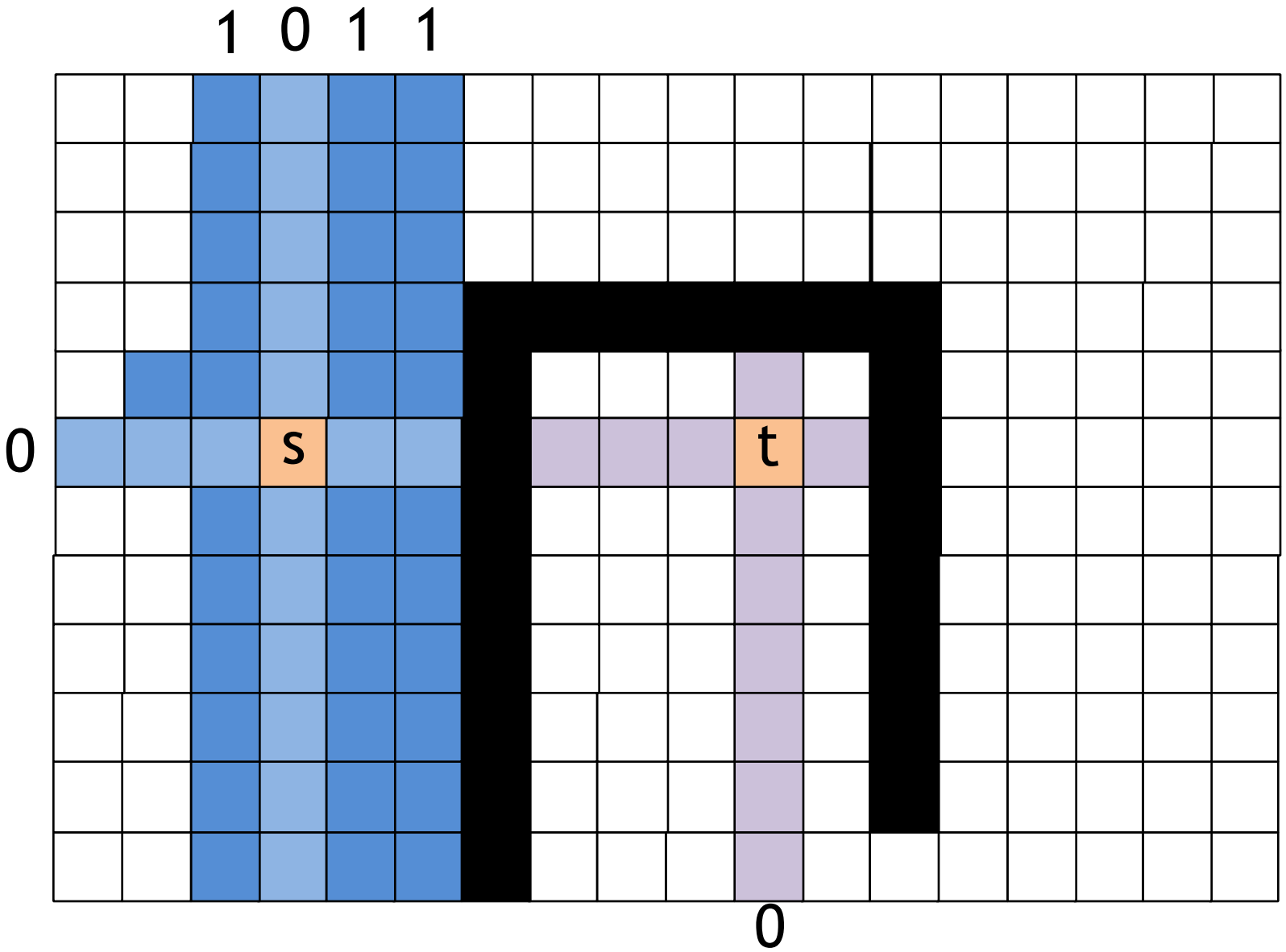
Source Line Probe (Level 1)



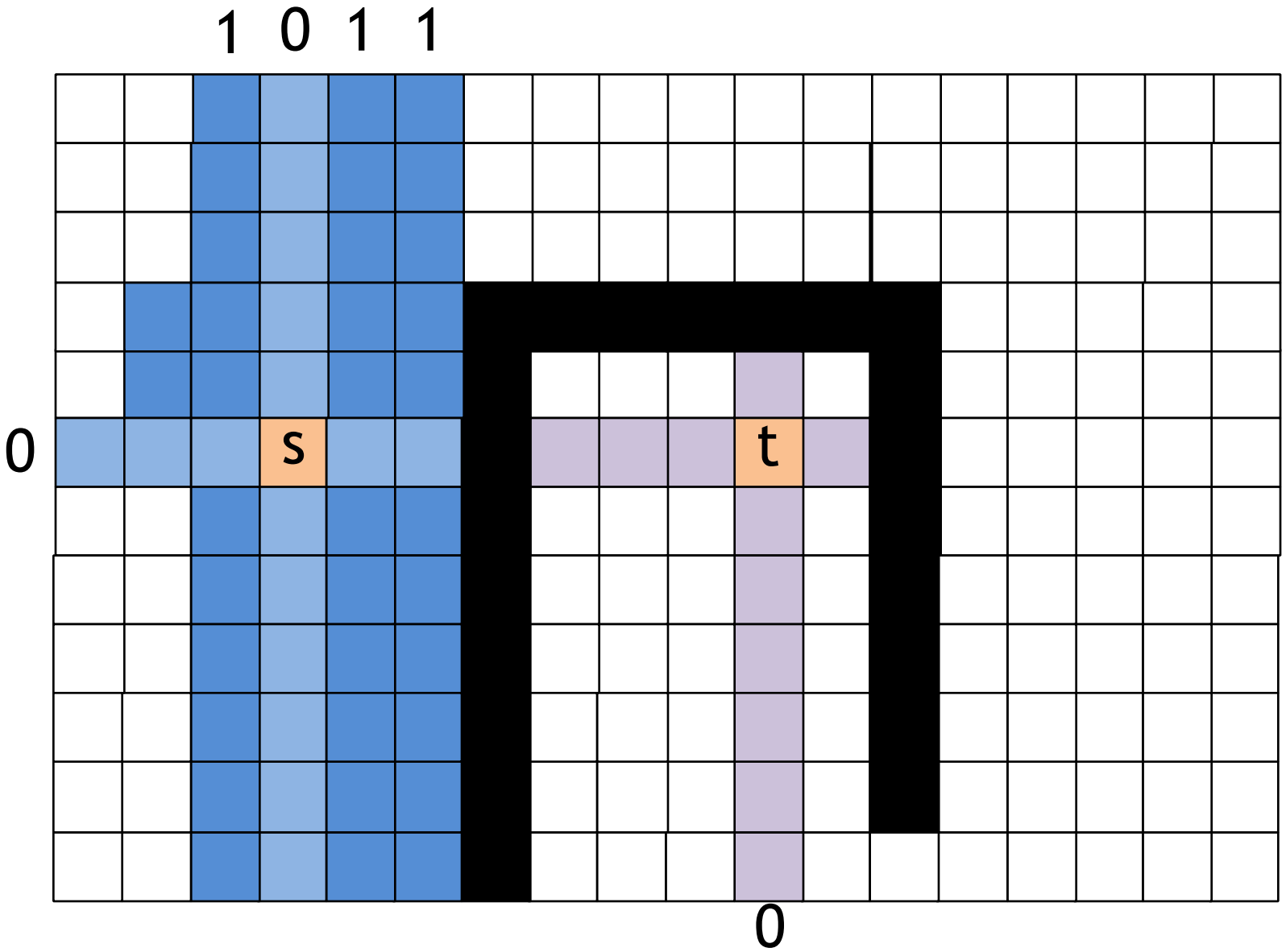
Source Line Probe (Level 1)



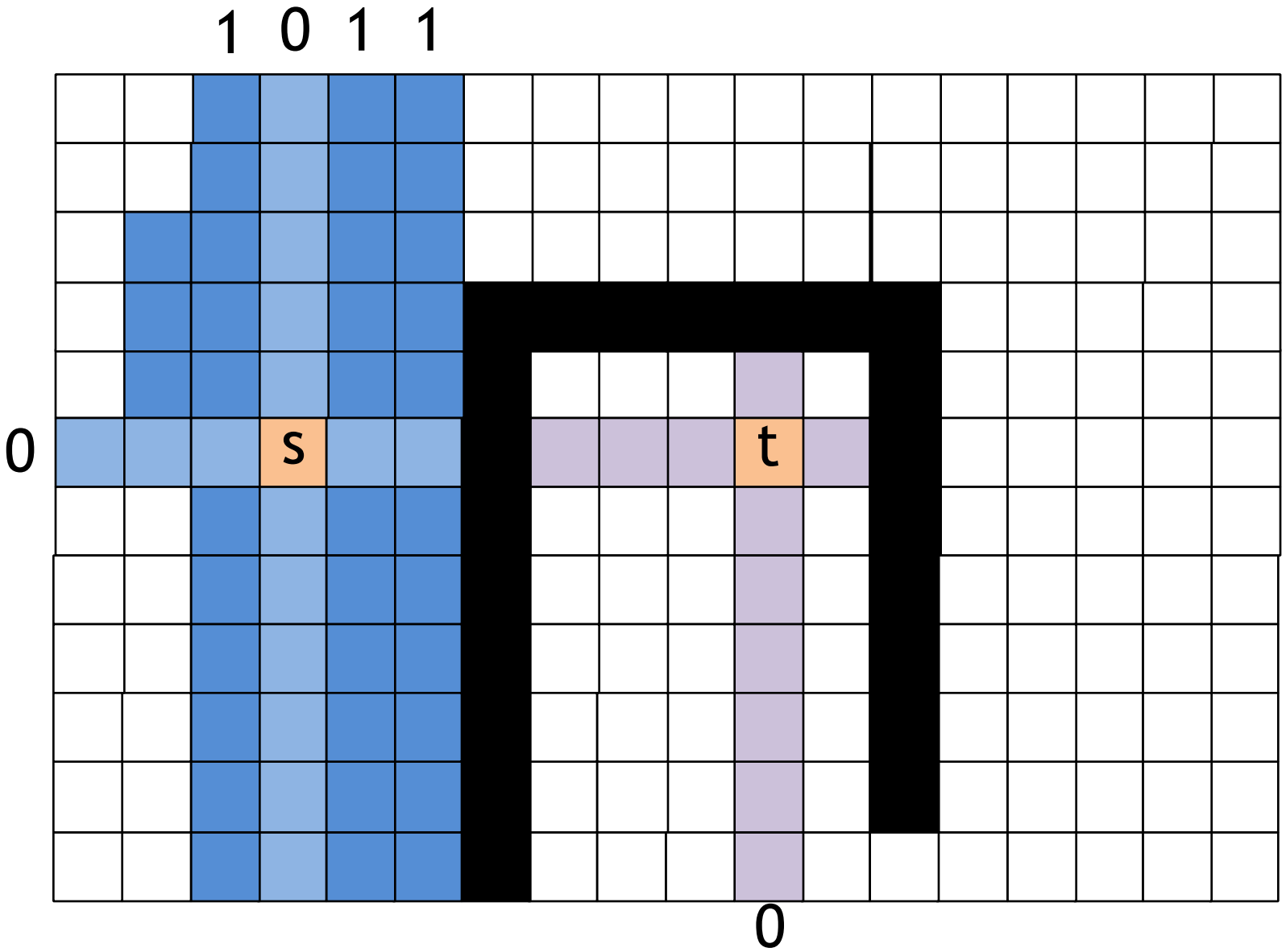
Source Line Probe (Level 1)



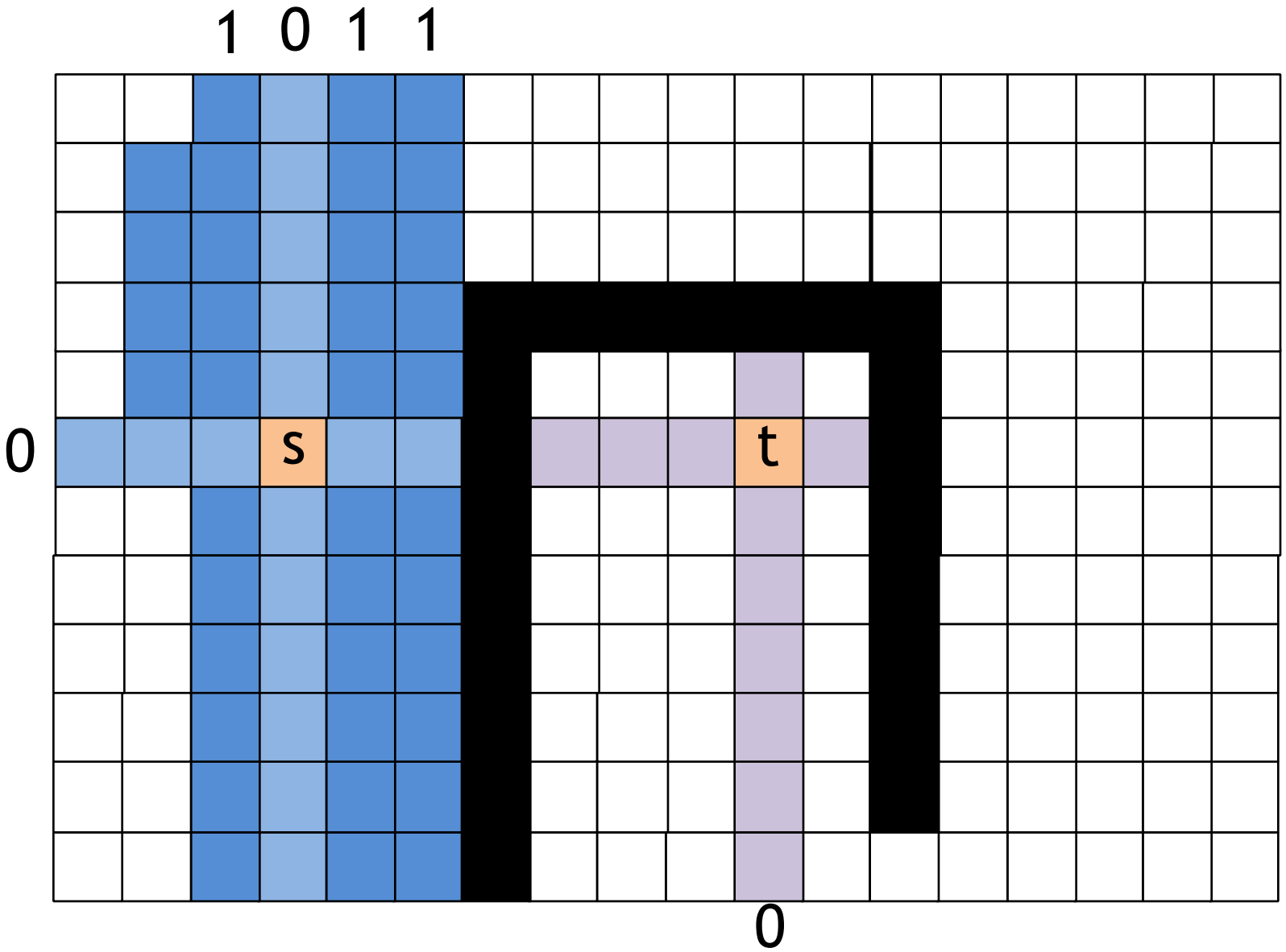
Source Line Probe (Level 1)



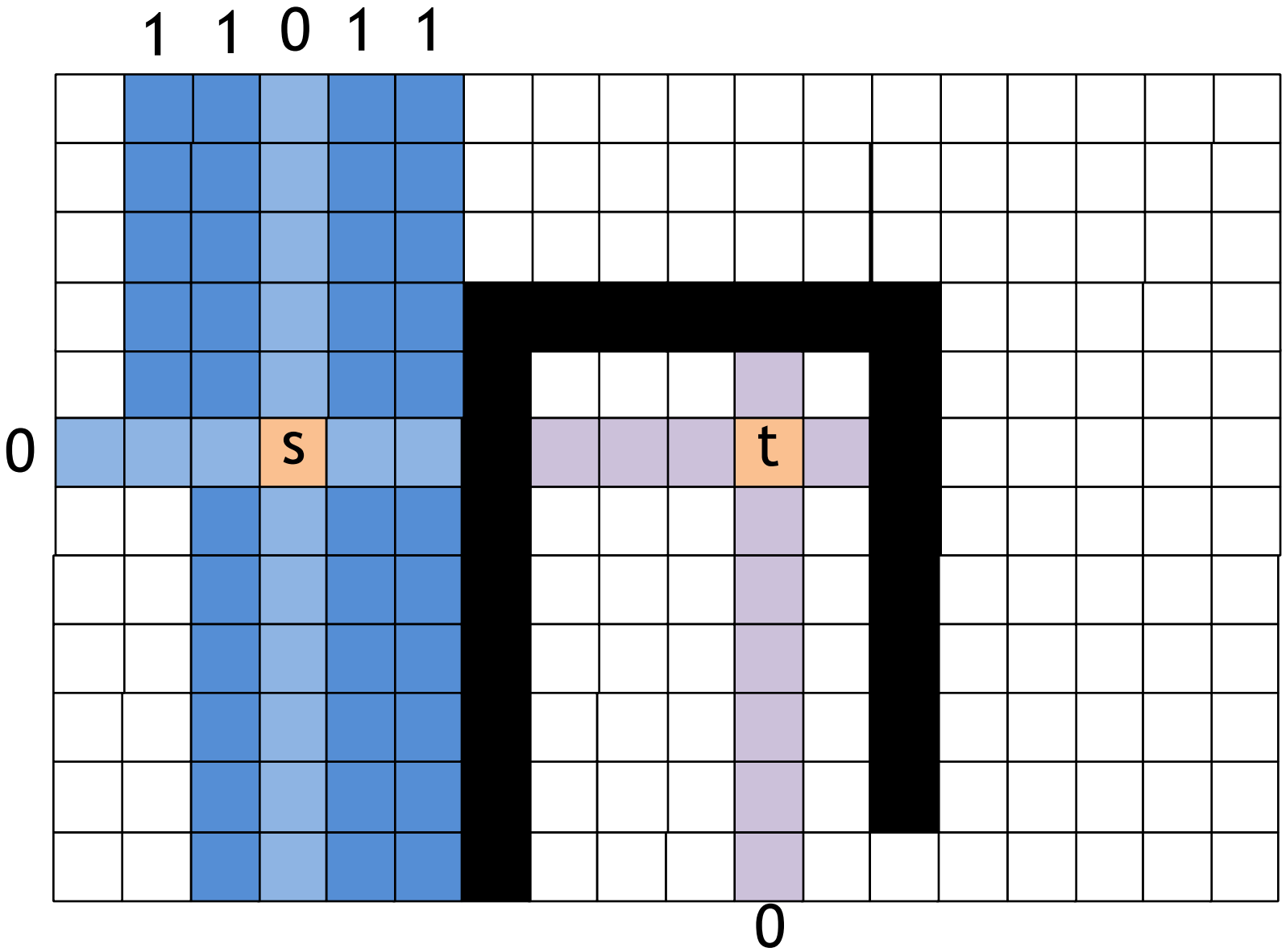
Source Line Probe (Level 1)



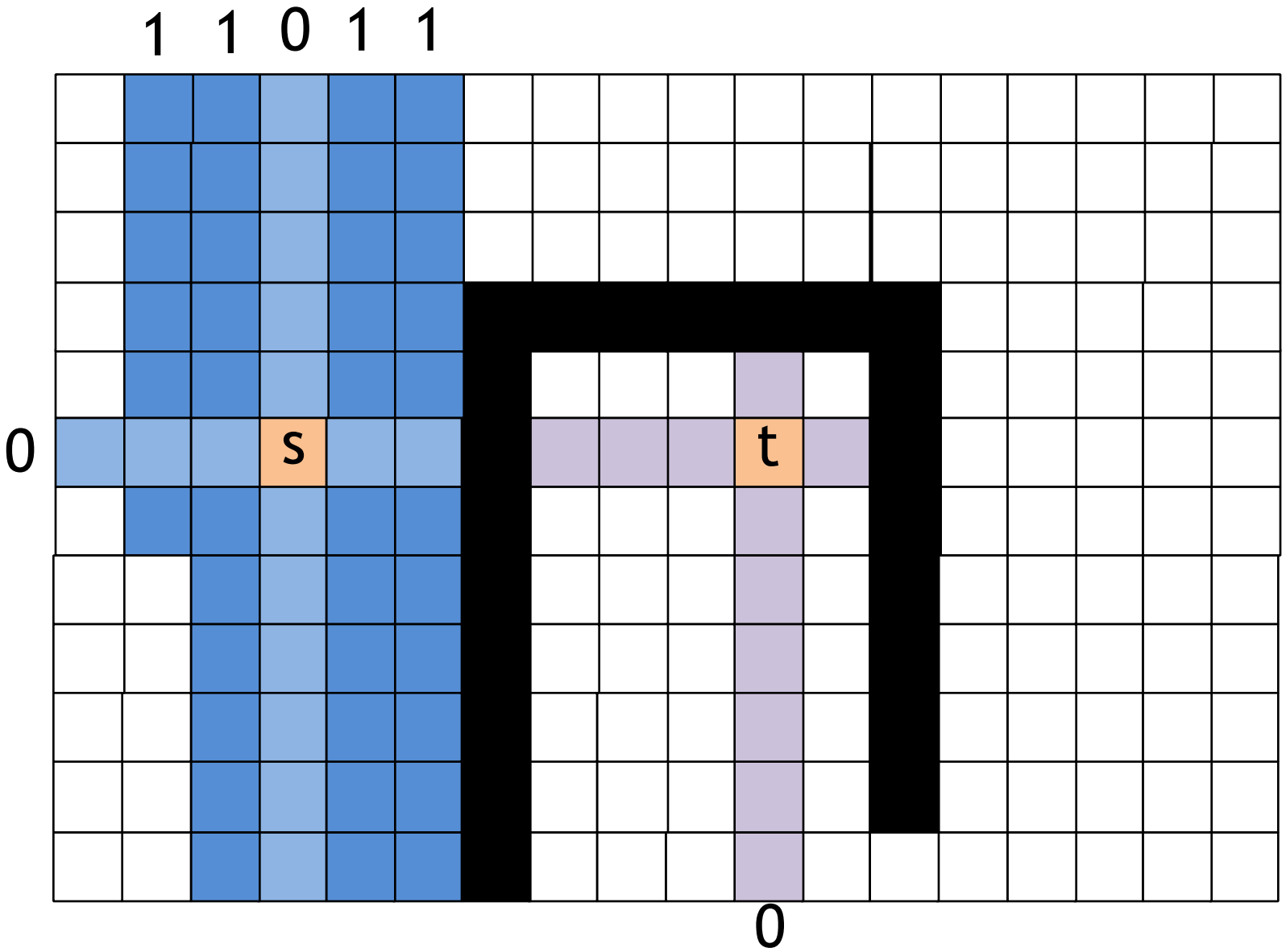
Source Line Probe (Level 1)



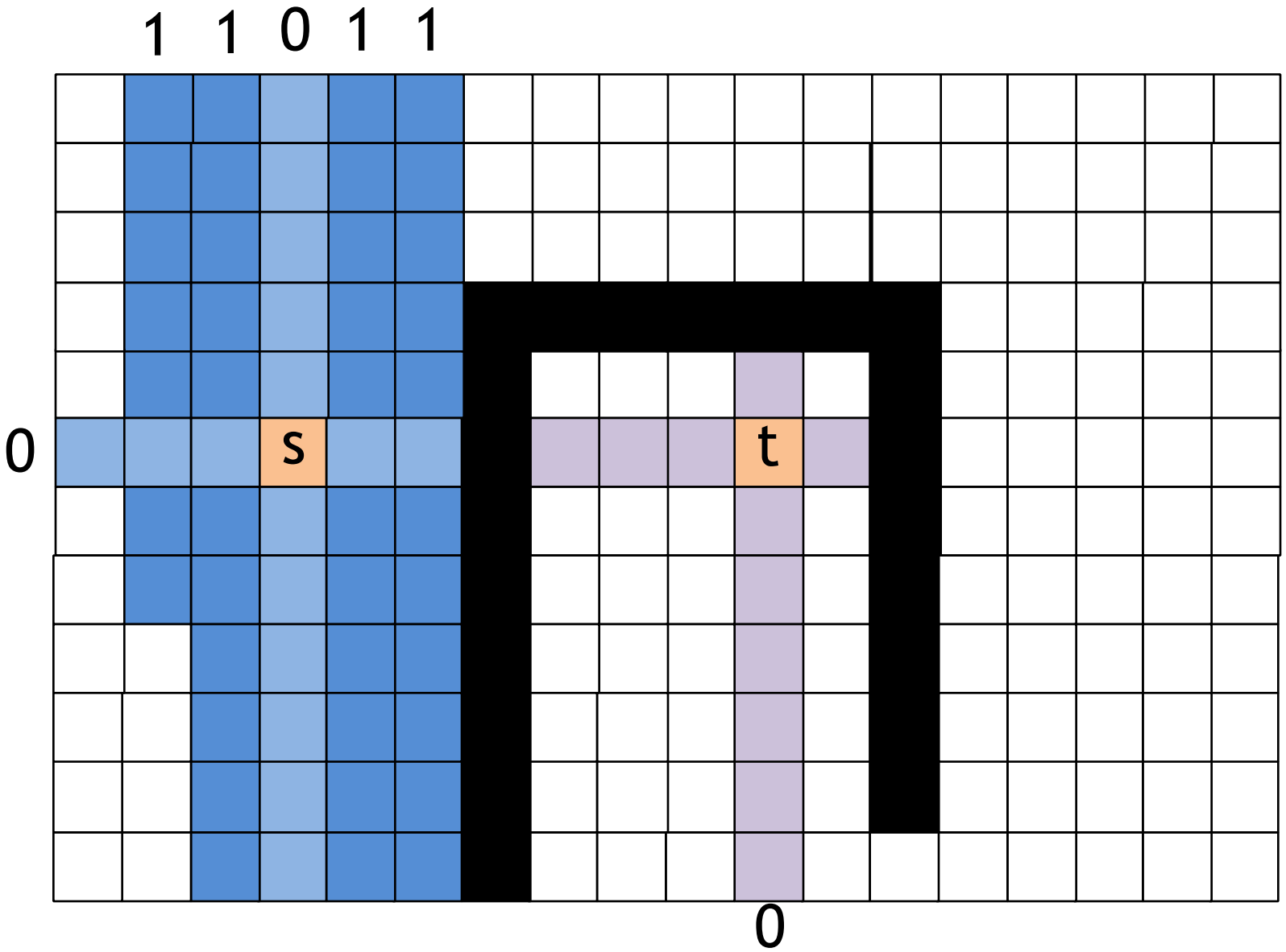
Source Line Probe (Level 1)



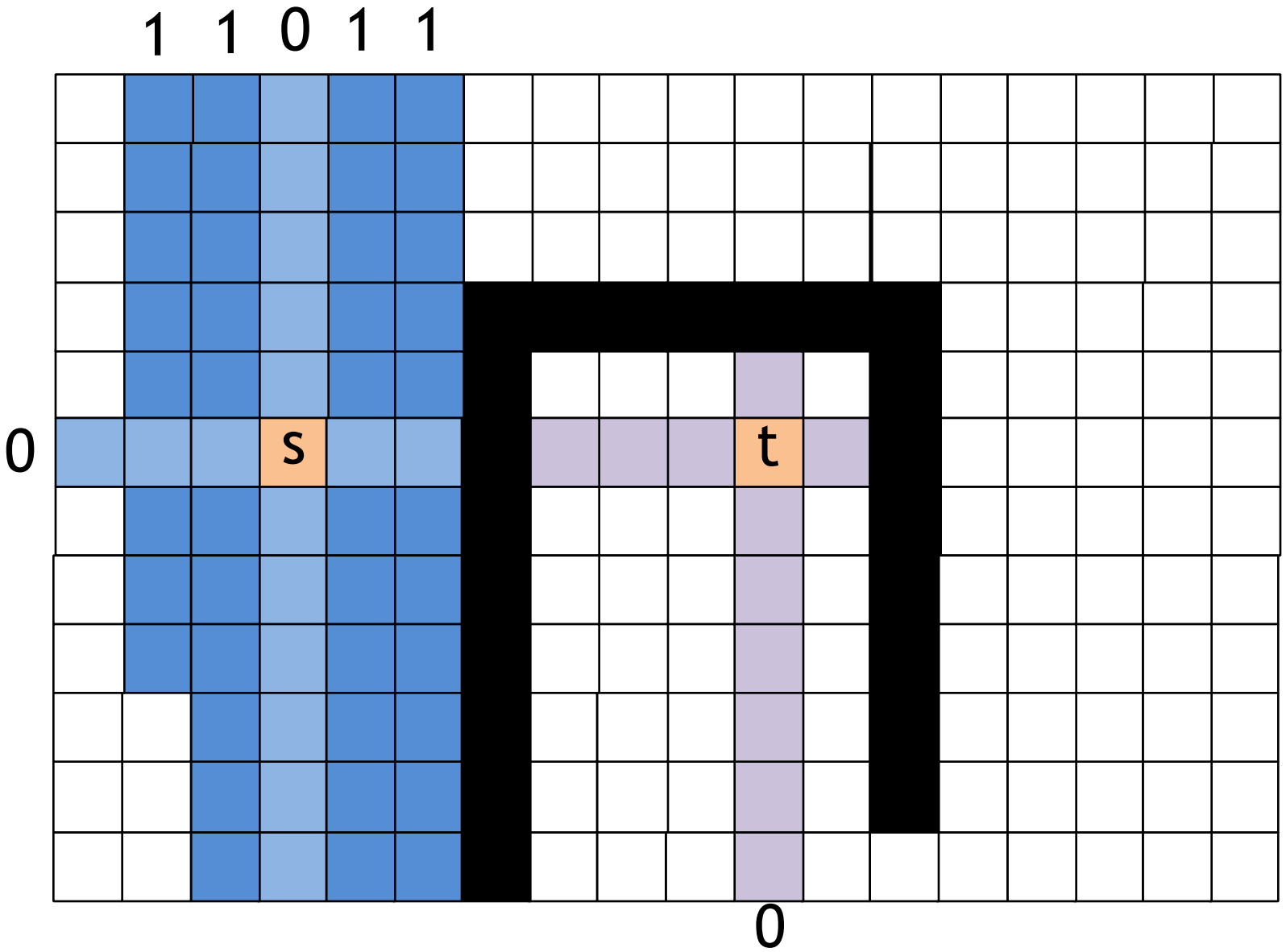
Source Line Probe (Level 1)



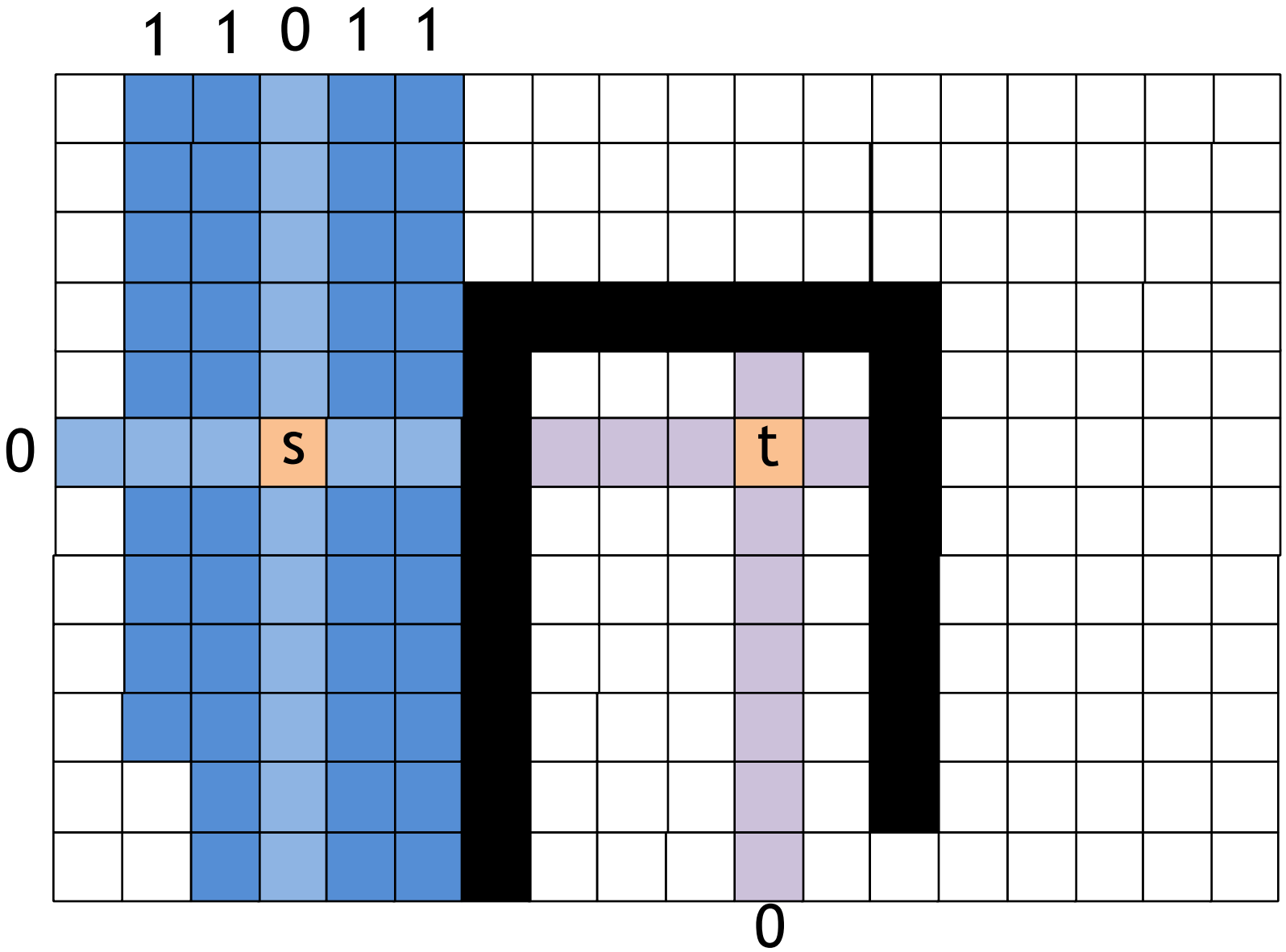
Source Line Probe (Level 1)



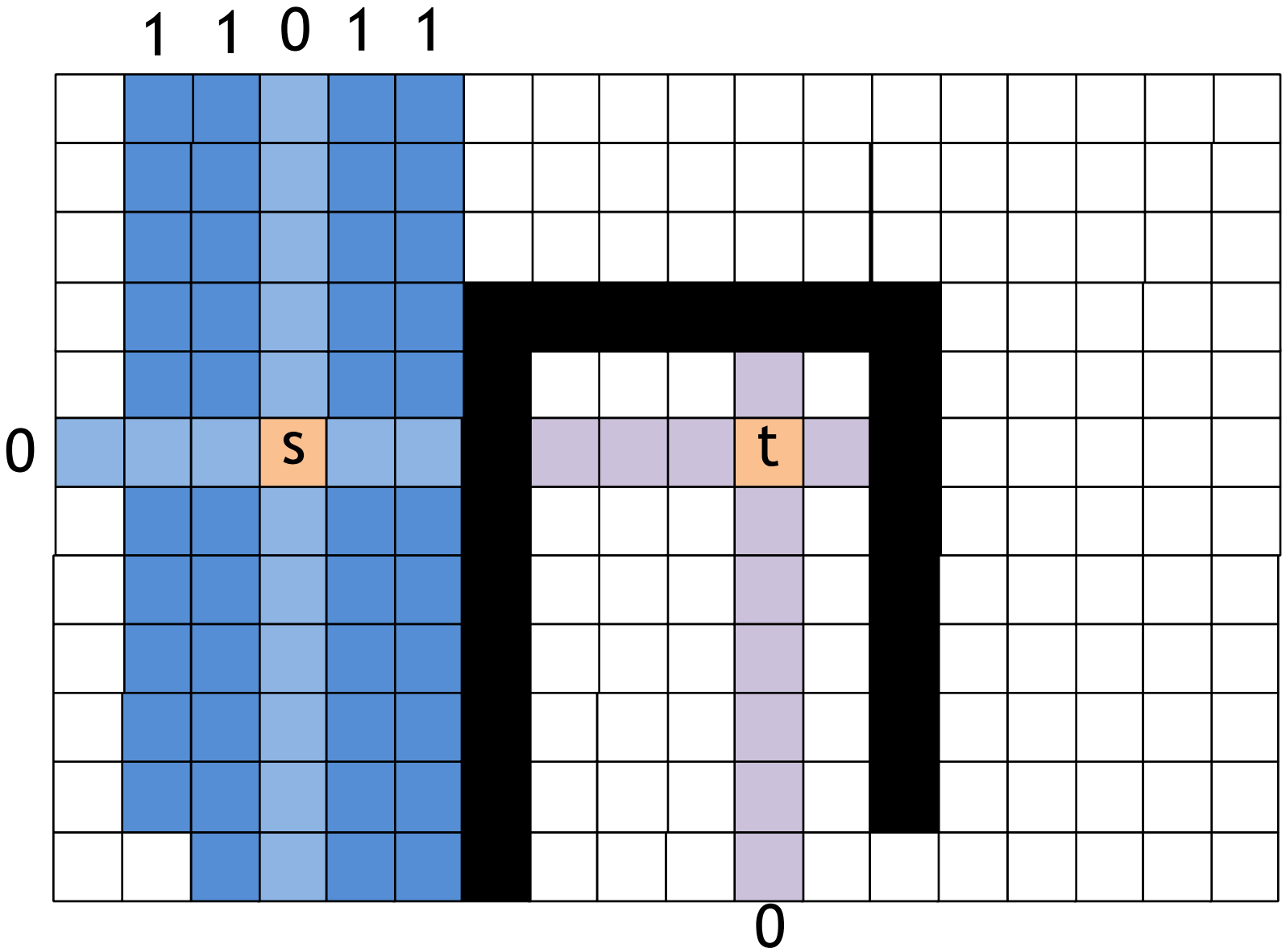
Source Line Probe (Level 1)



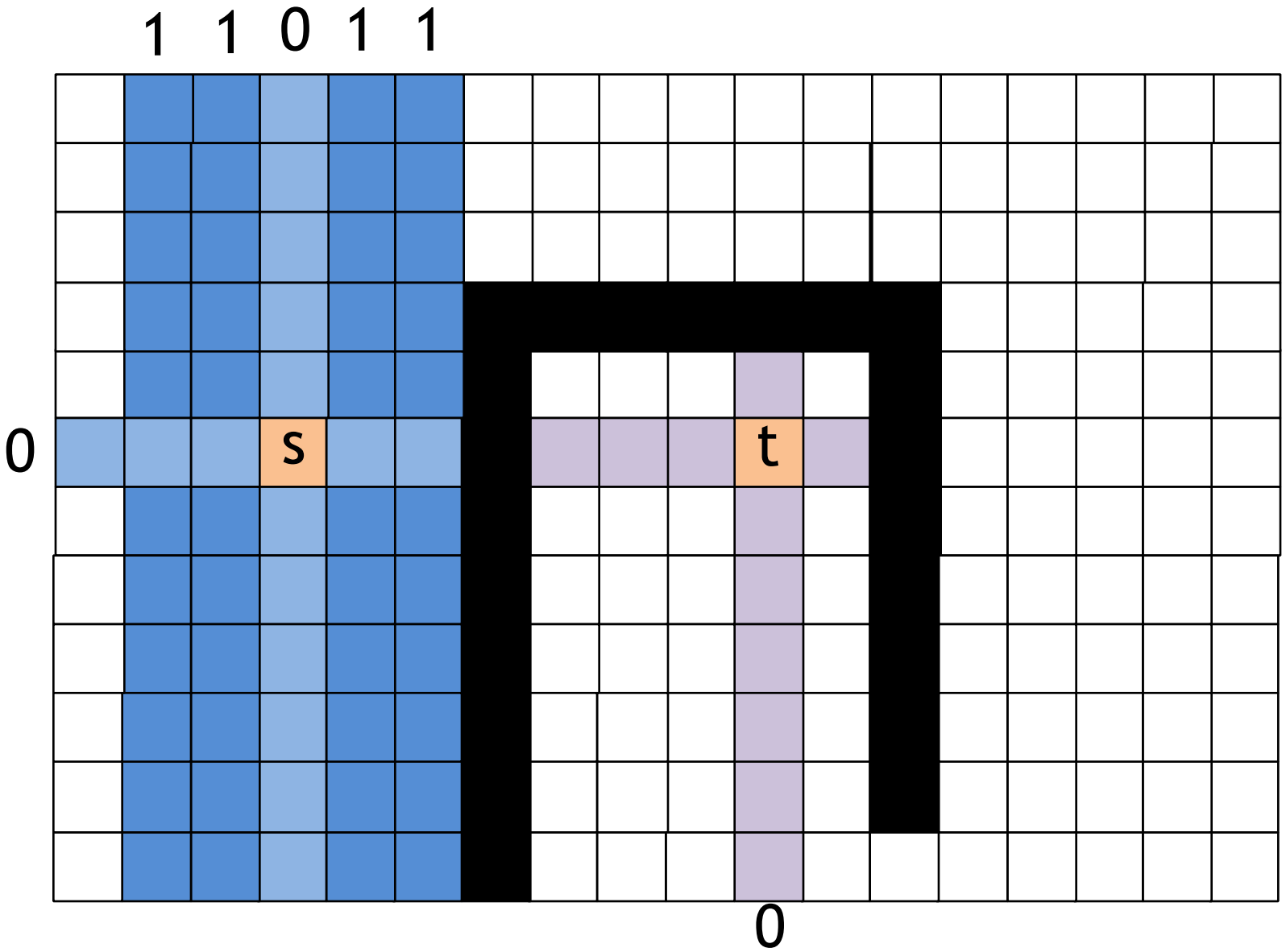
Source Line Probe (Level 1)



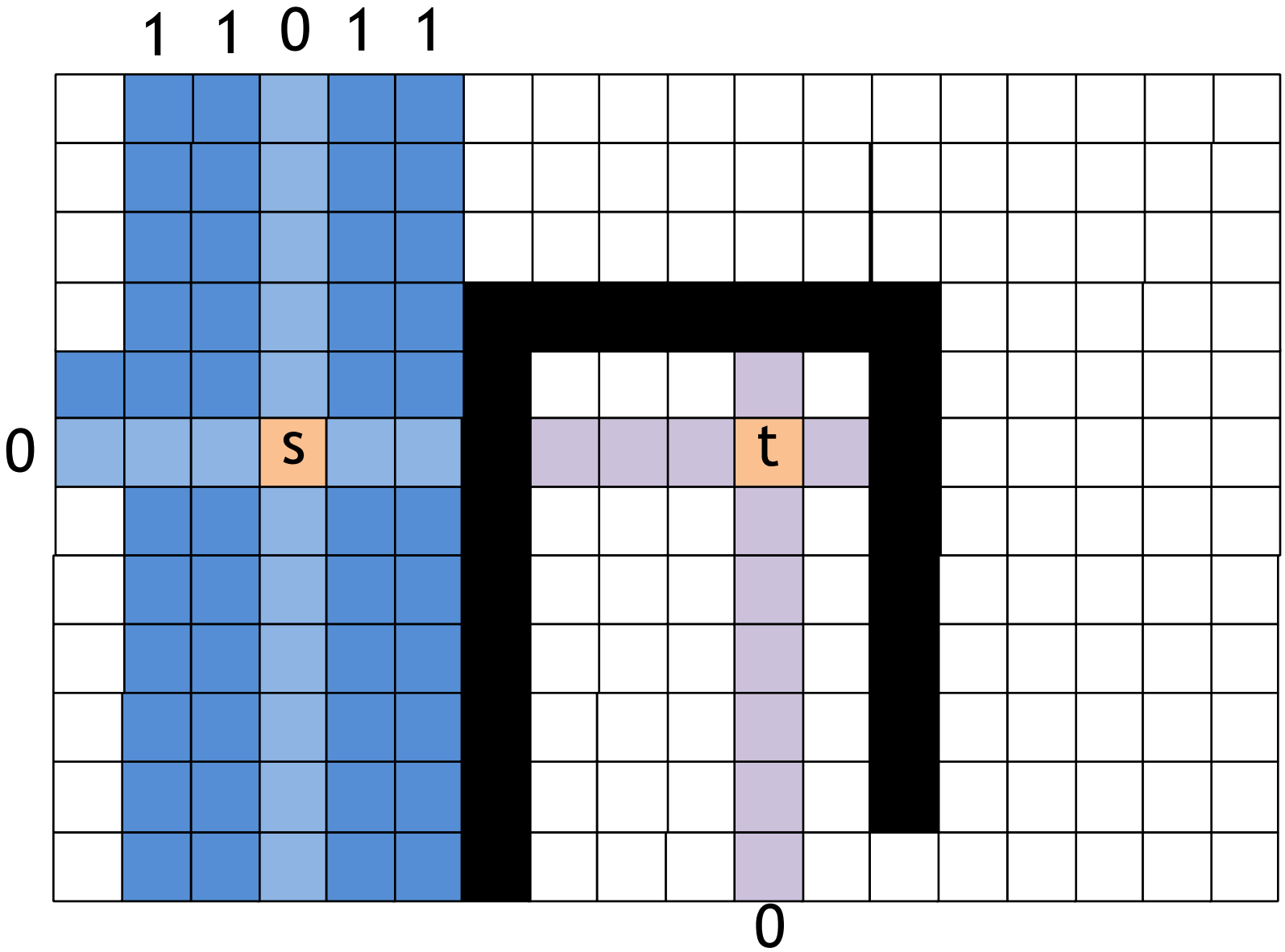
Source Line Probe (Level 1)



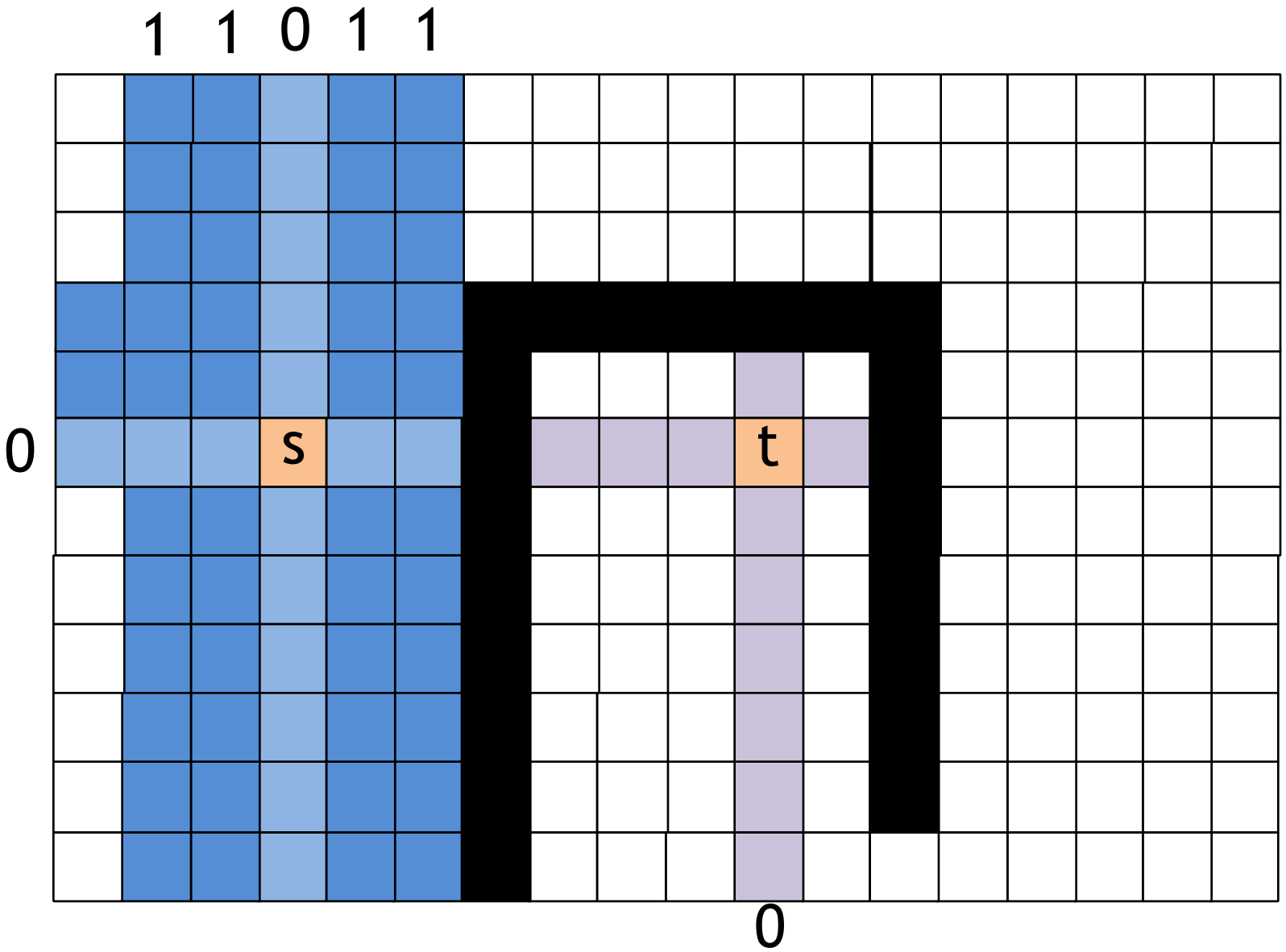
Source Line Probe (Level 1)



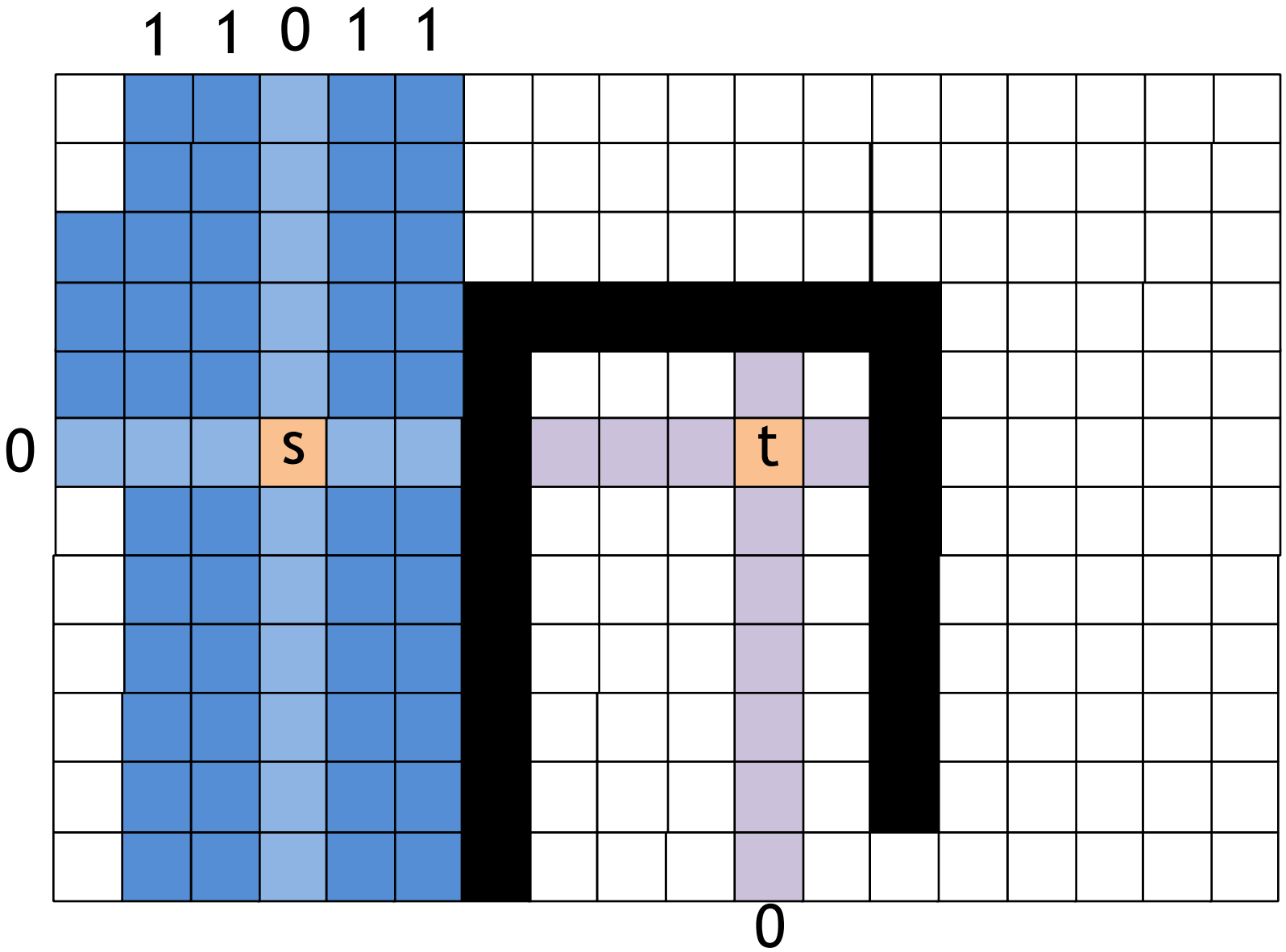
Source Line Probe (Level 1)



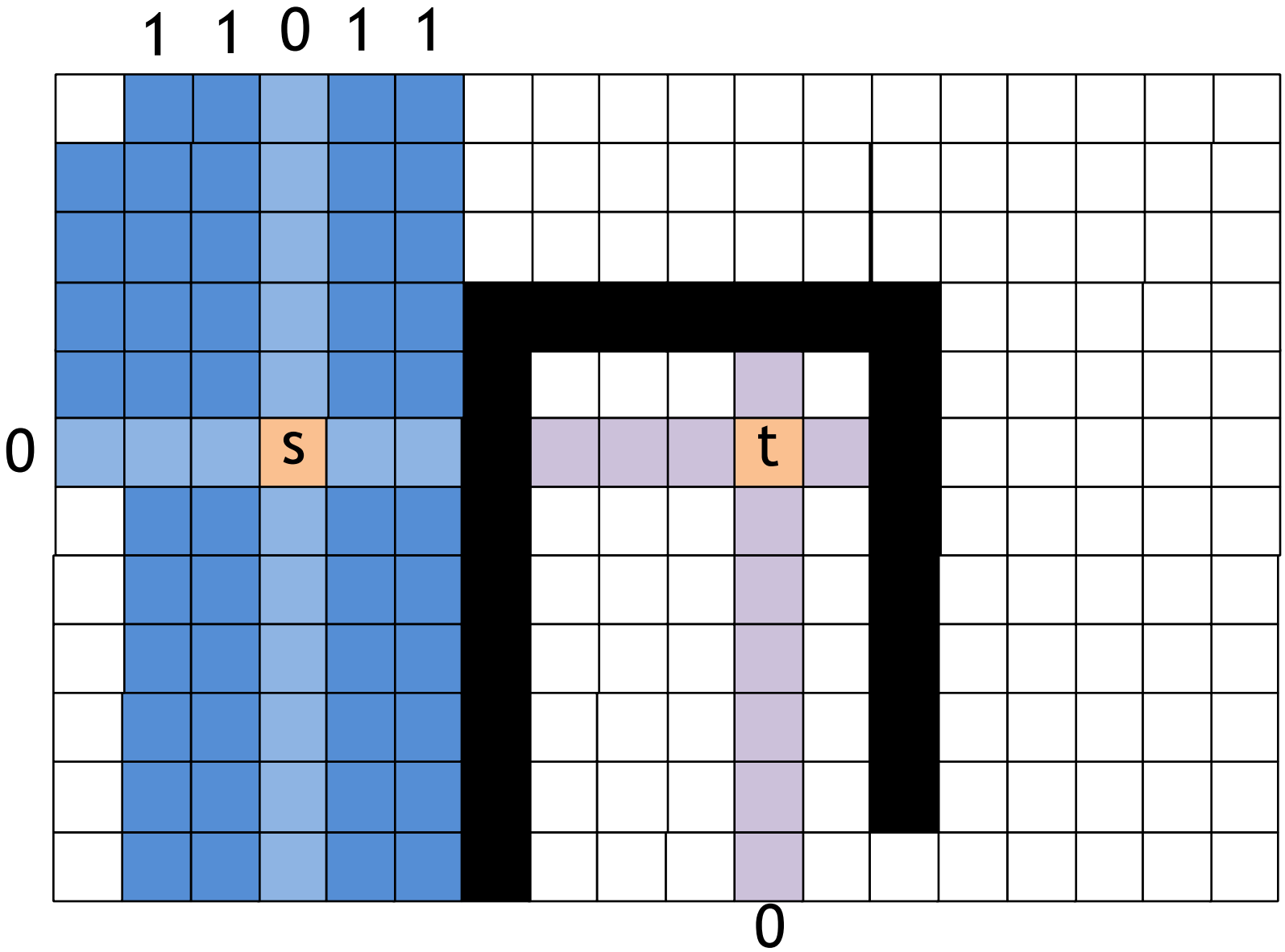
Source Line Probe (Level 1)



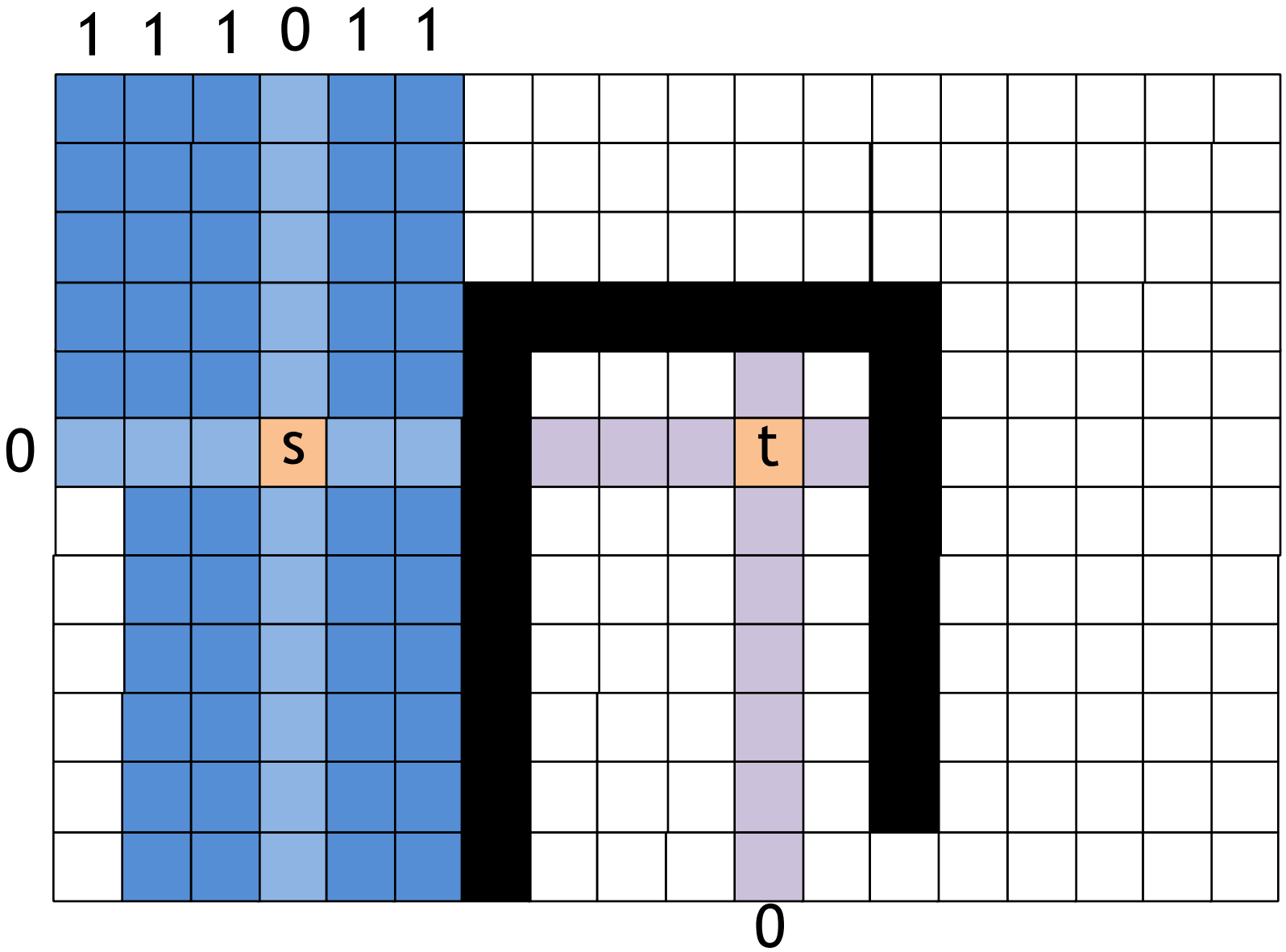
Source Line Probe (Level 1)



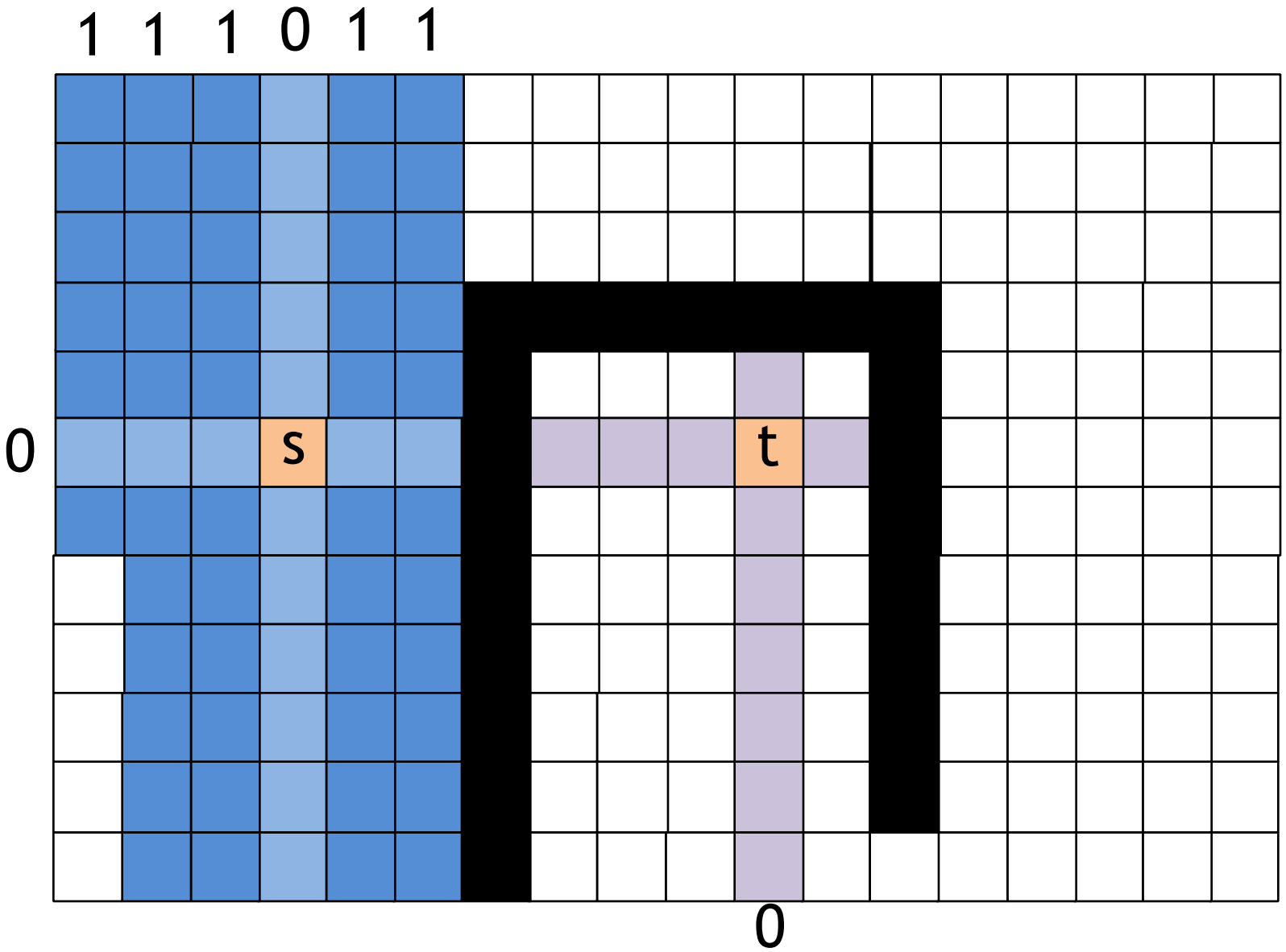
Source Line Probe (Level 1)



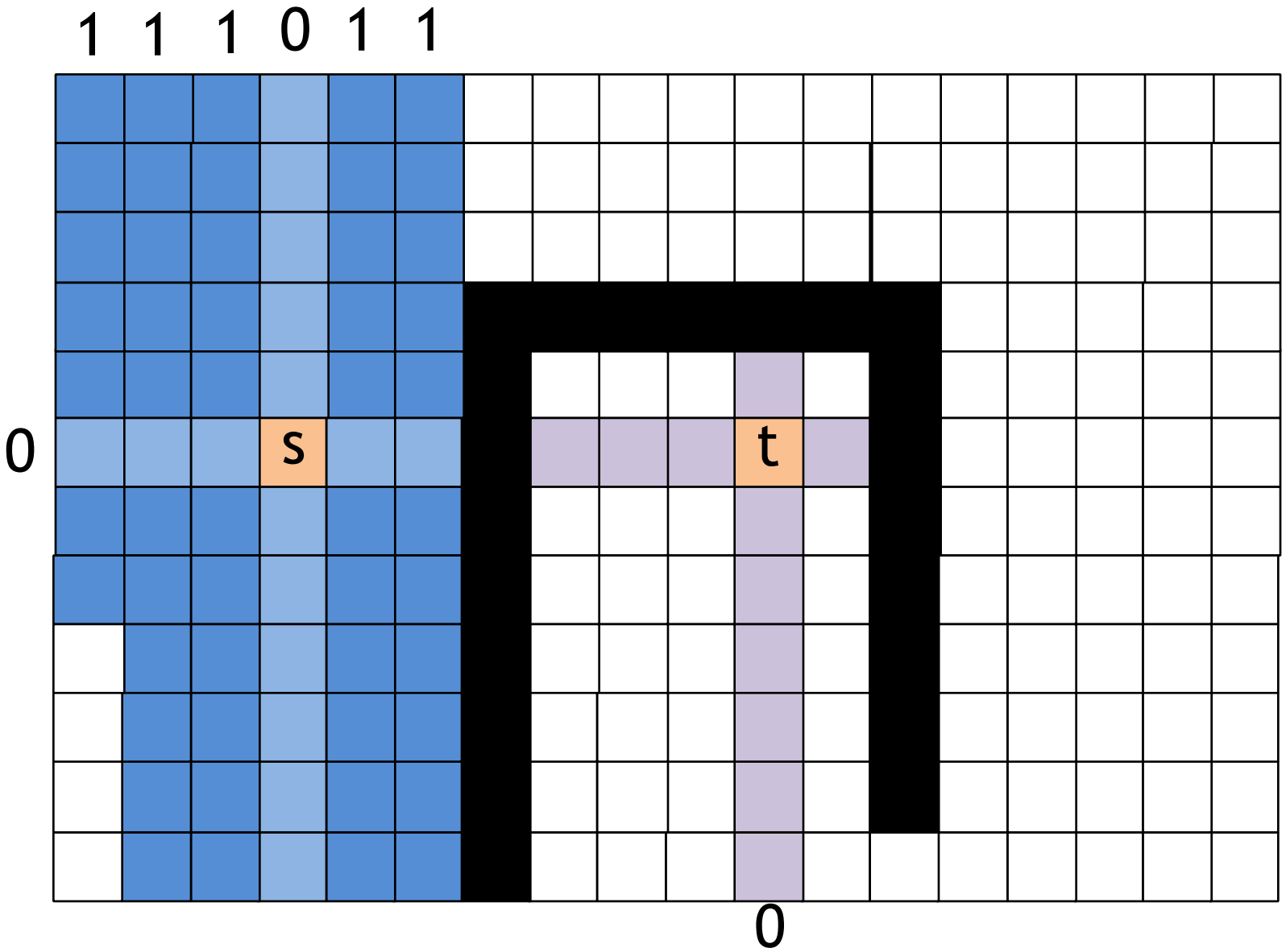
Source Line Probe (Level 1)



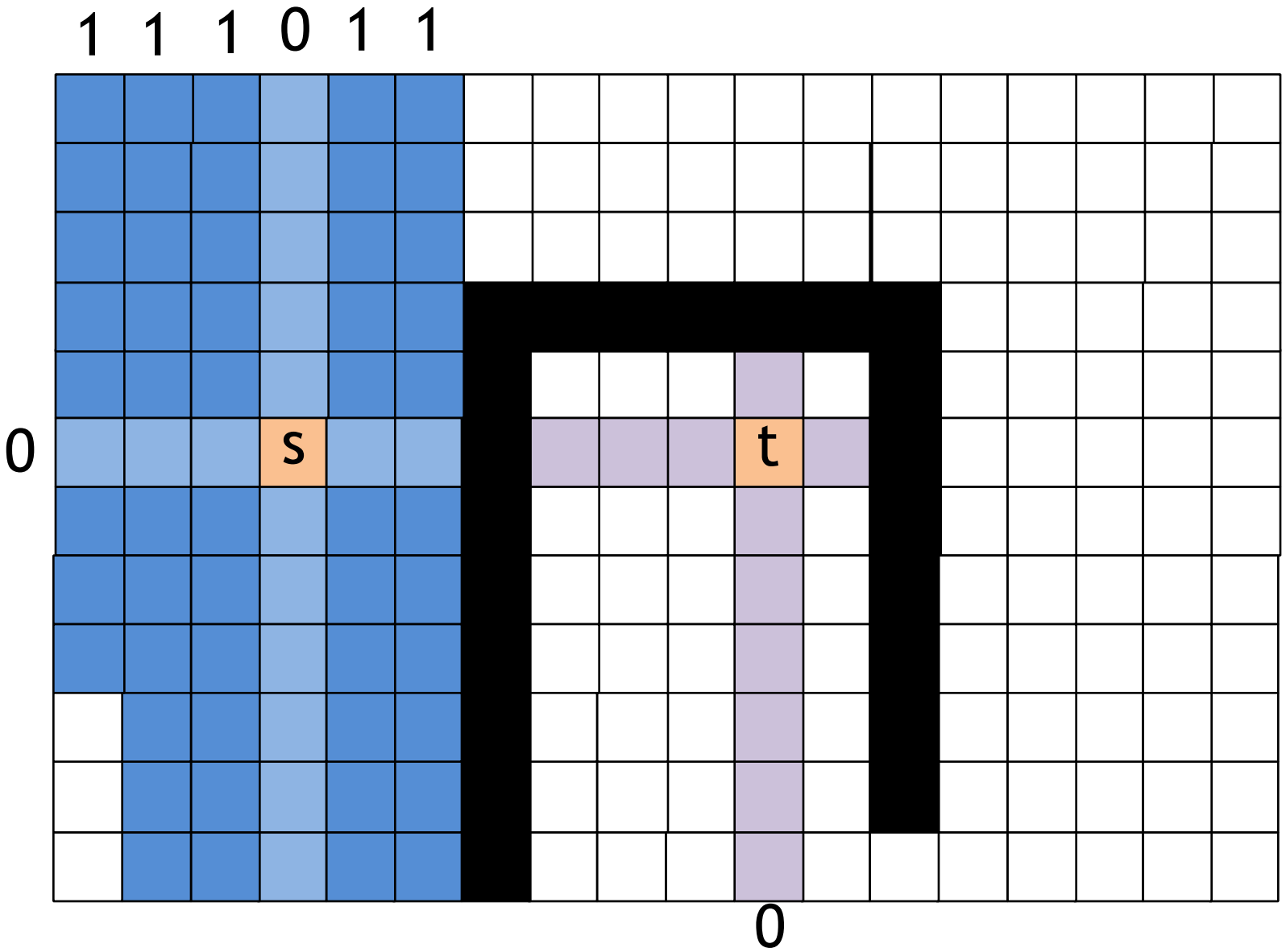
Source Line Probe (Level 1)



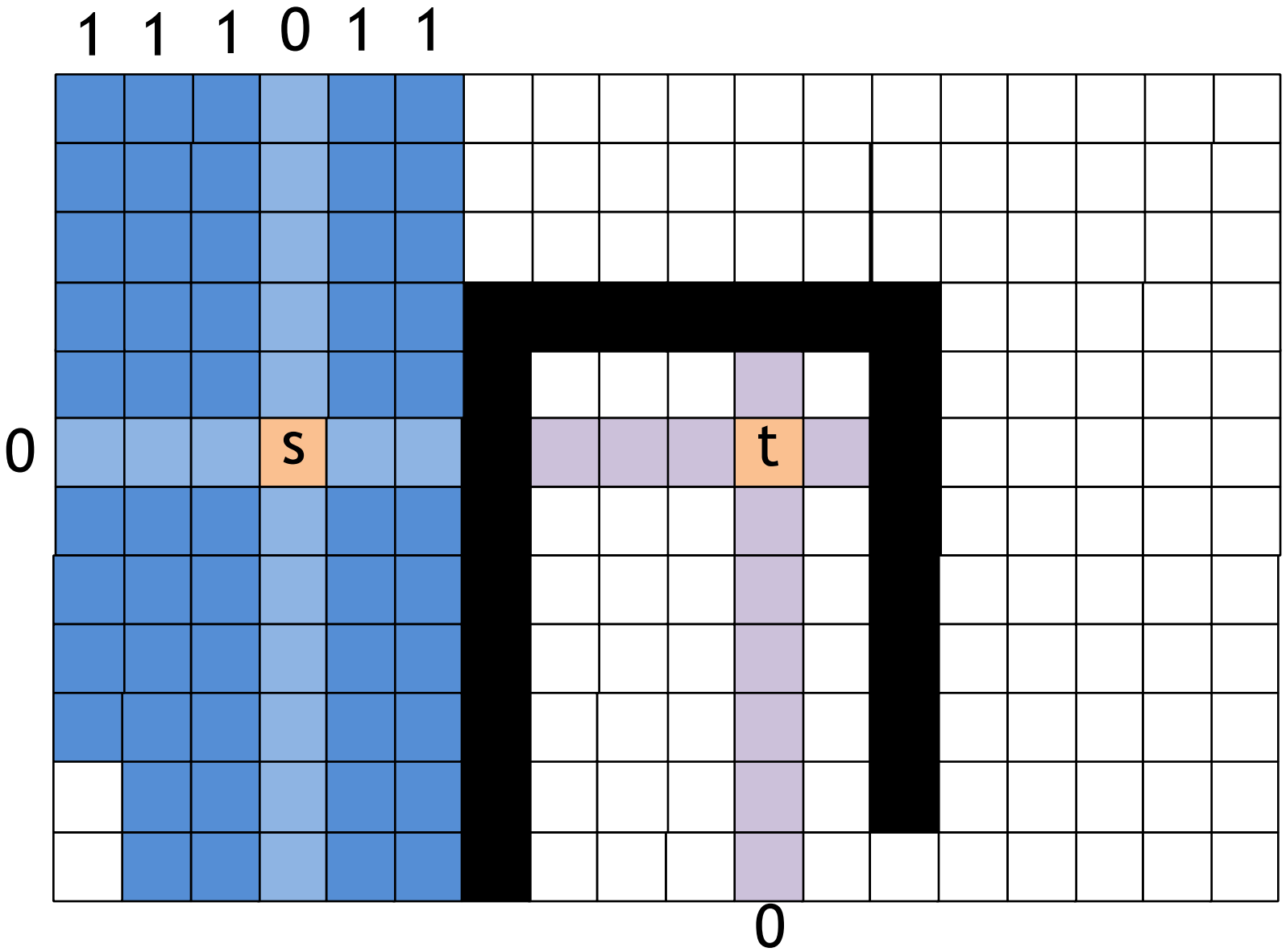
Source Line Probe (Level 1)



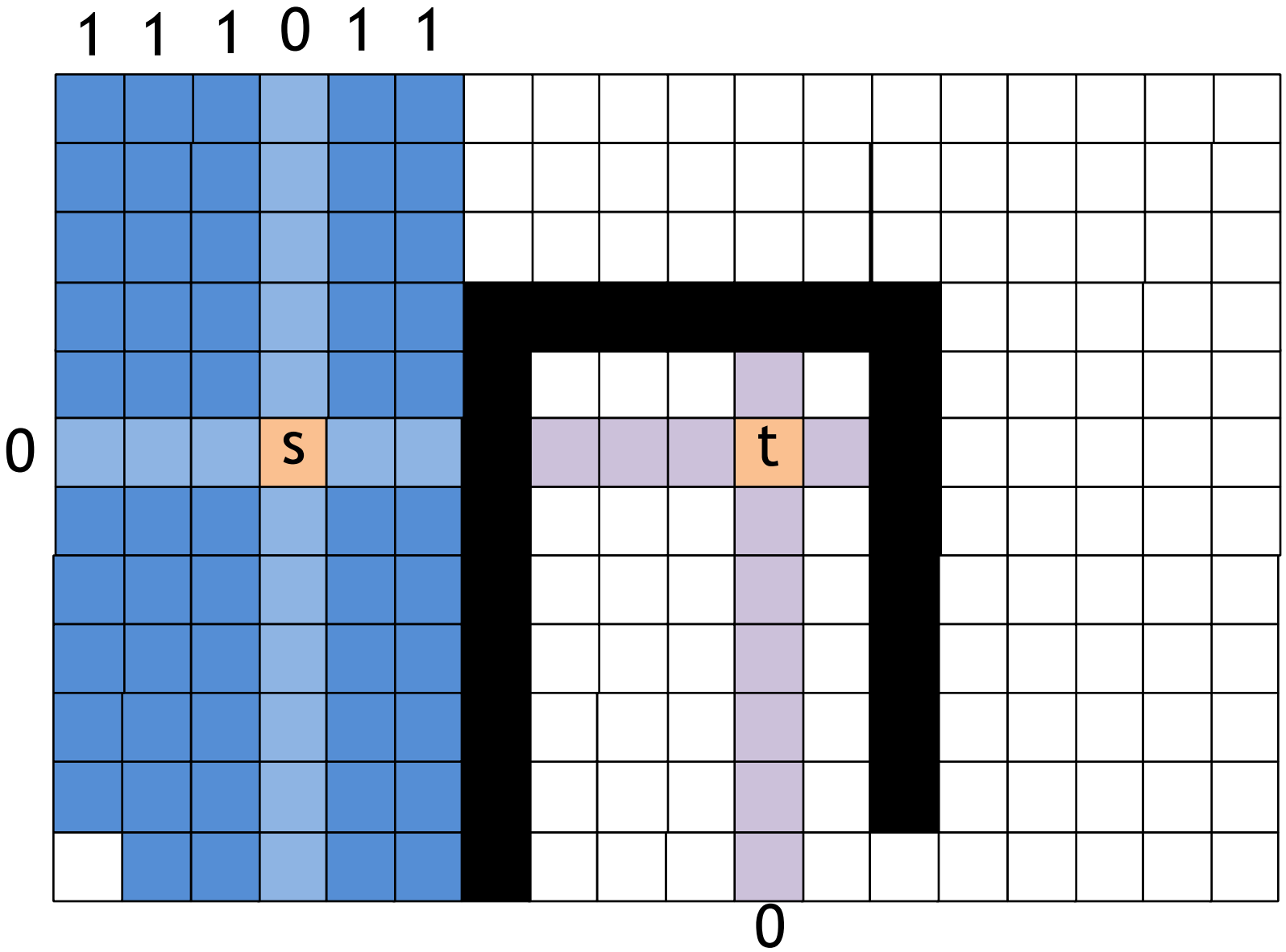
Source Line Probe (Level 1)



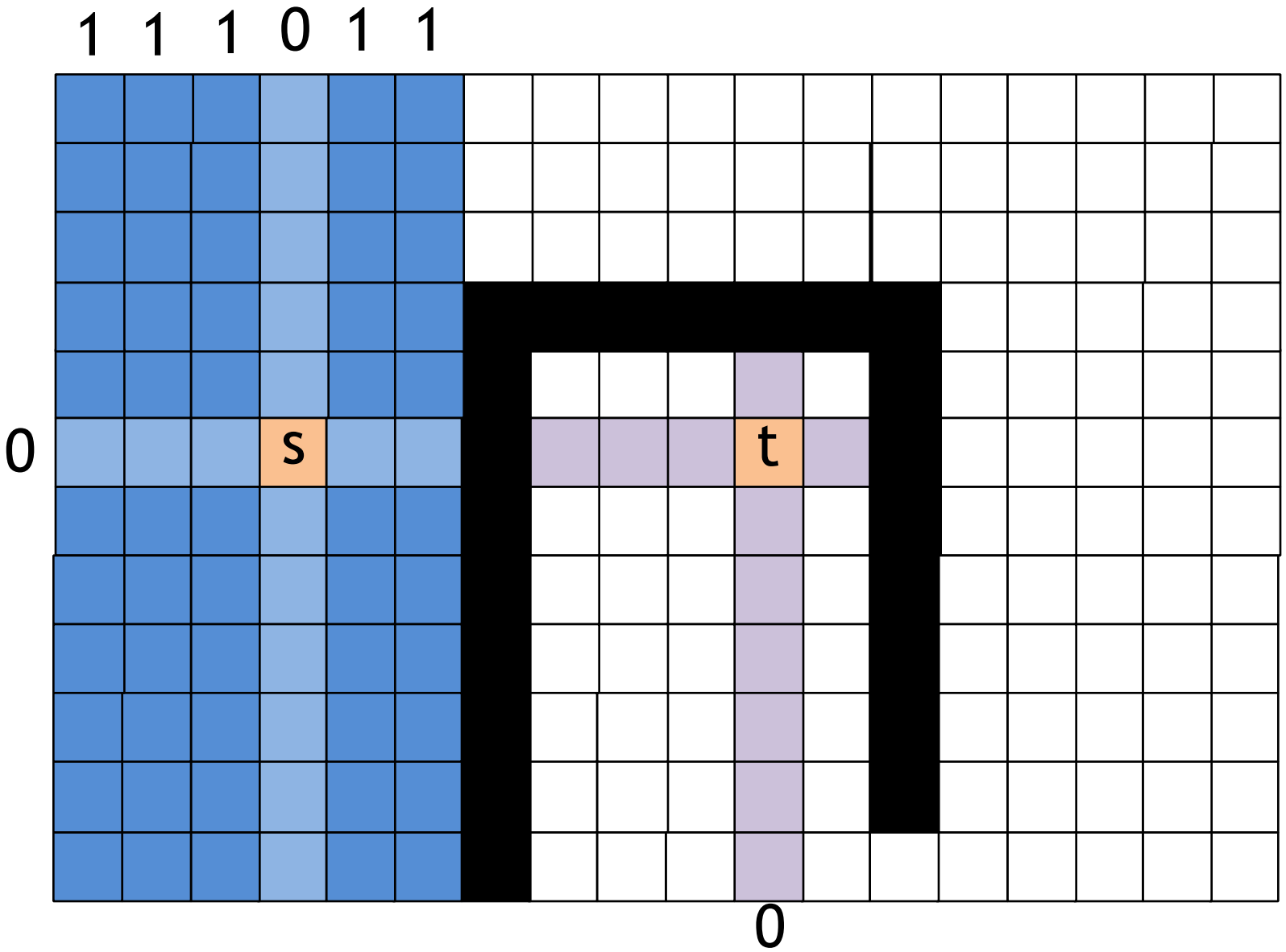
Source Line Probe (Level 1)



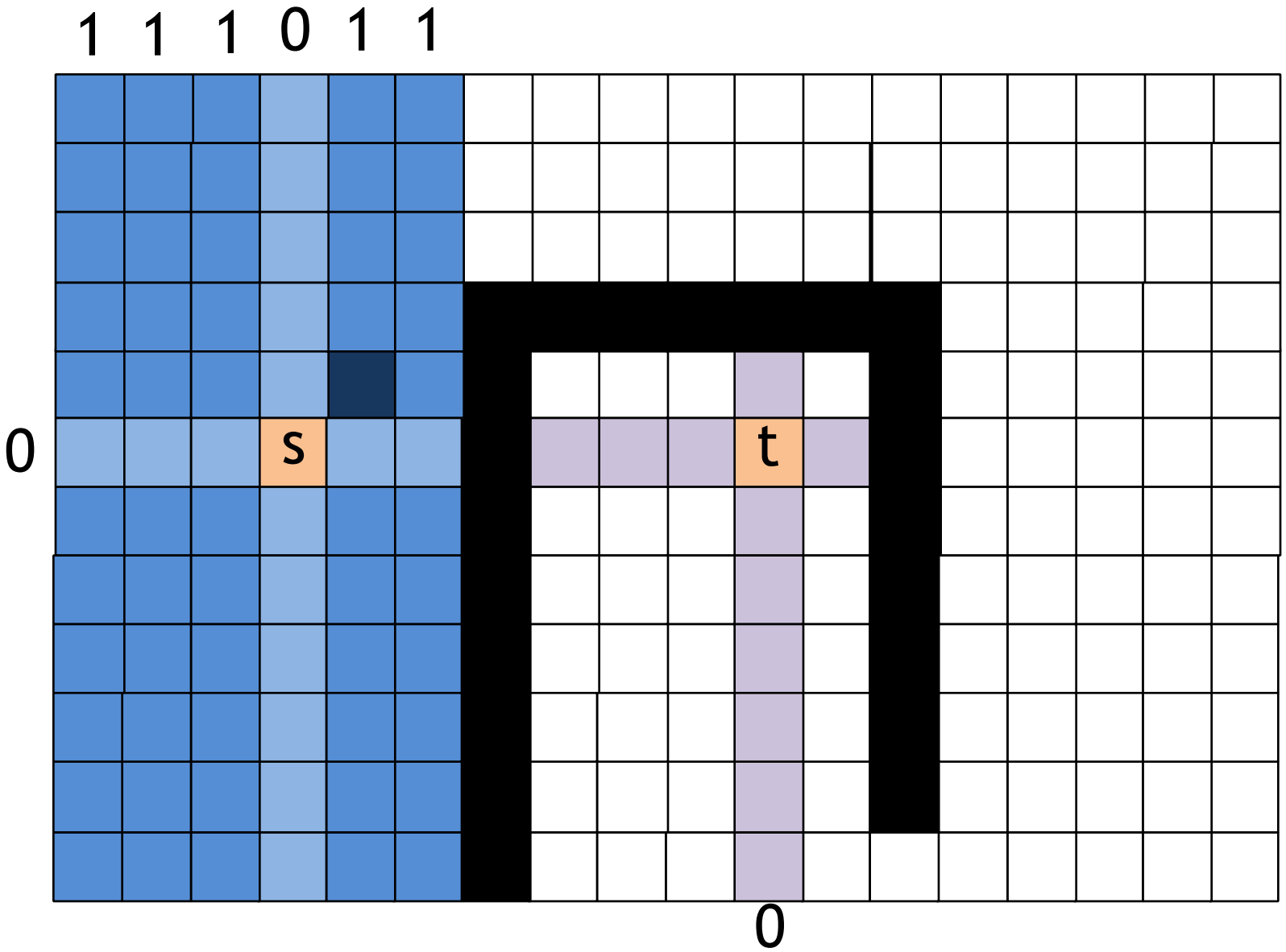
Source Line Probe (Level 1)



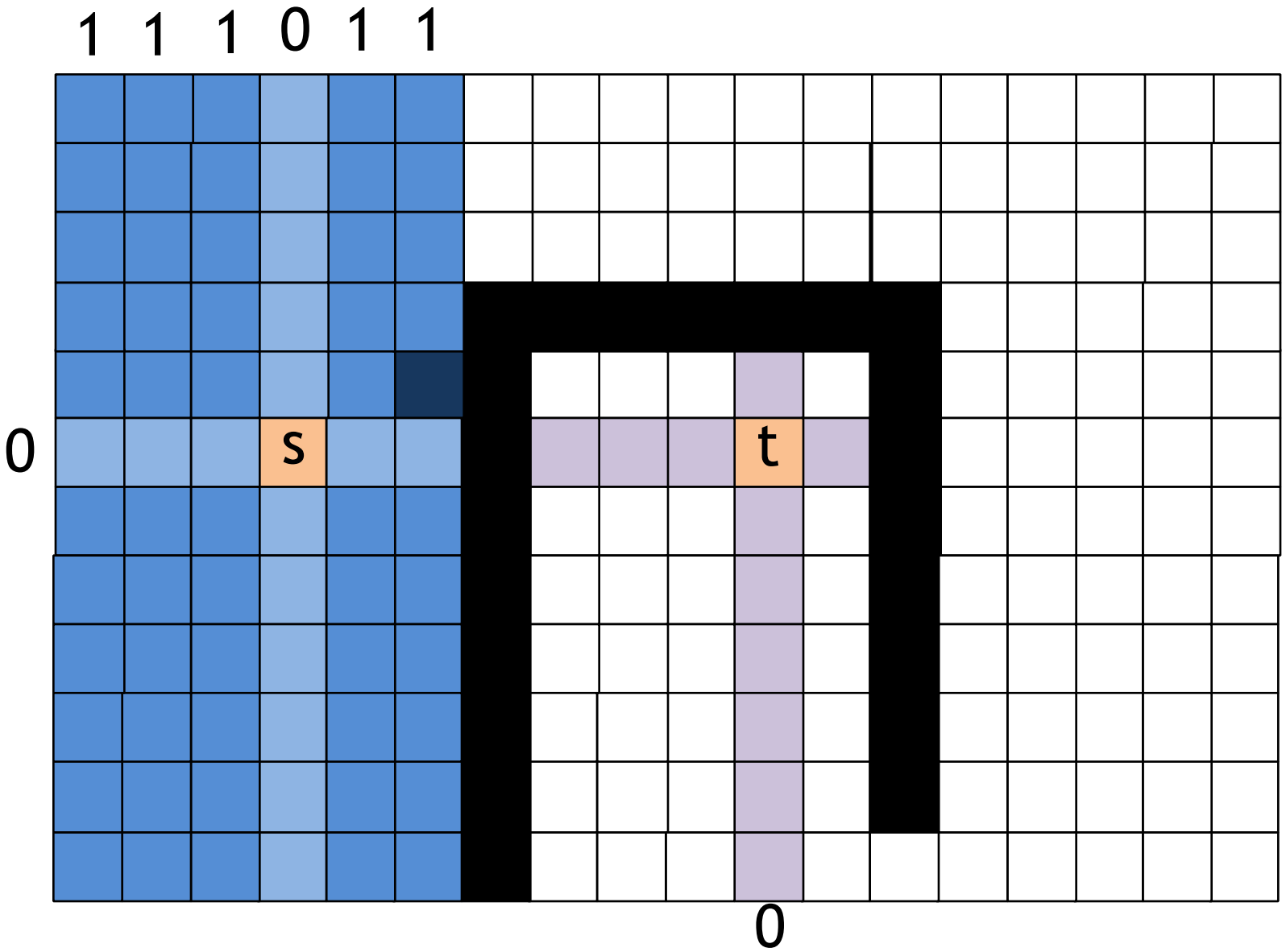
Source Line Probe (Level 1)



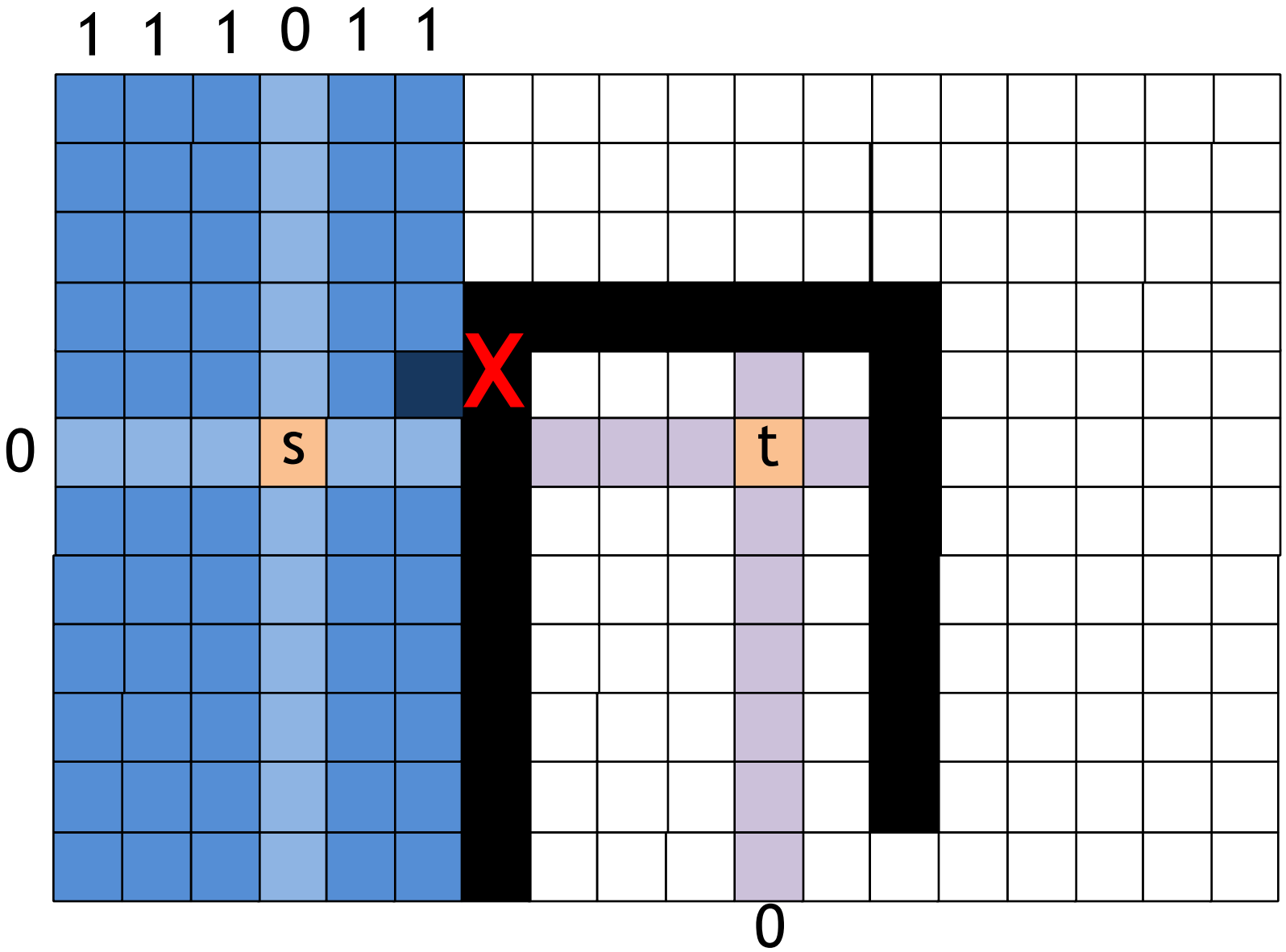
Source Line Probe (Level 1)



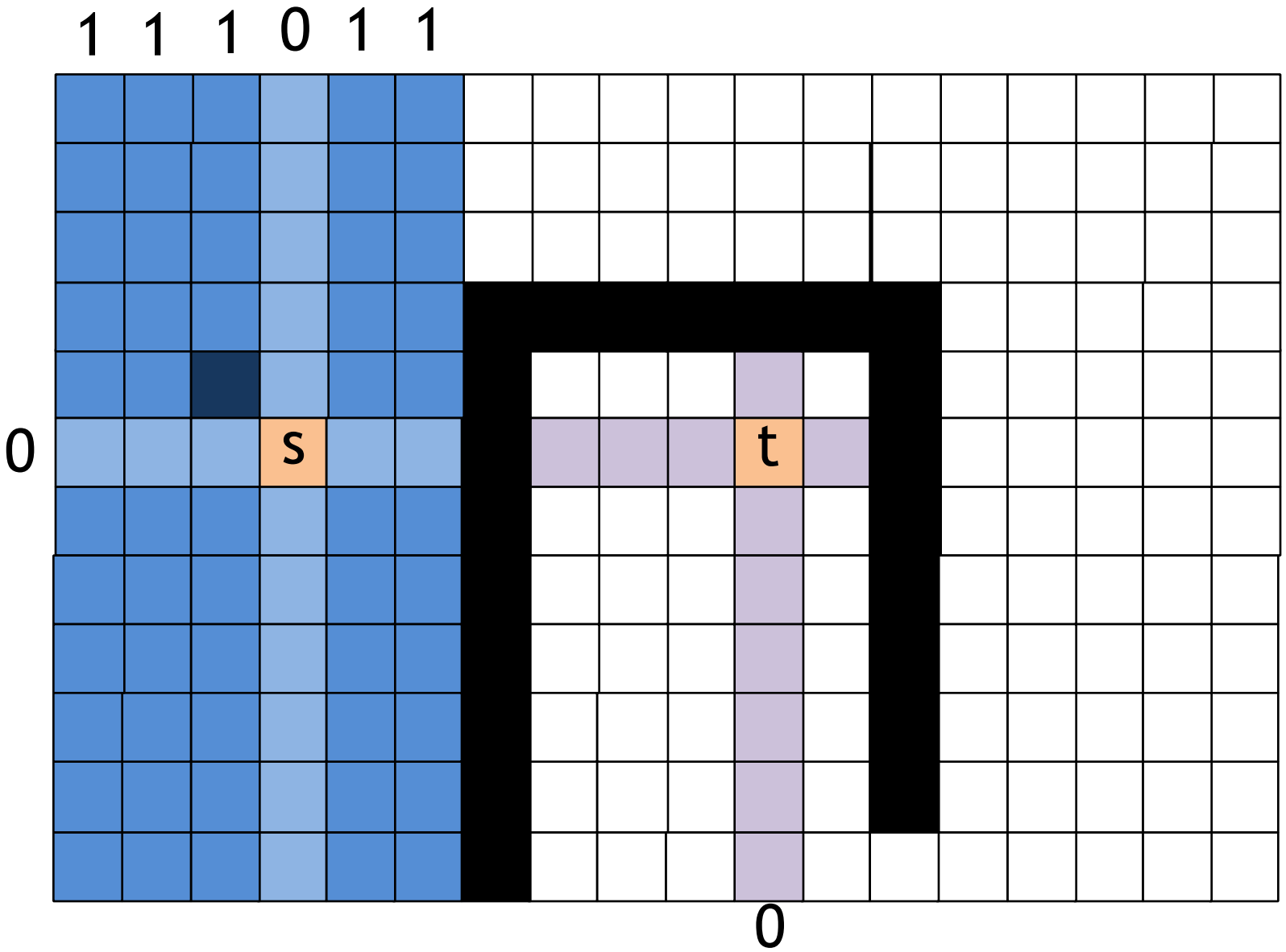
Source Line Probe (Level 1)



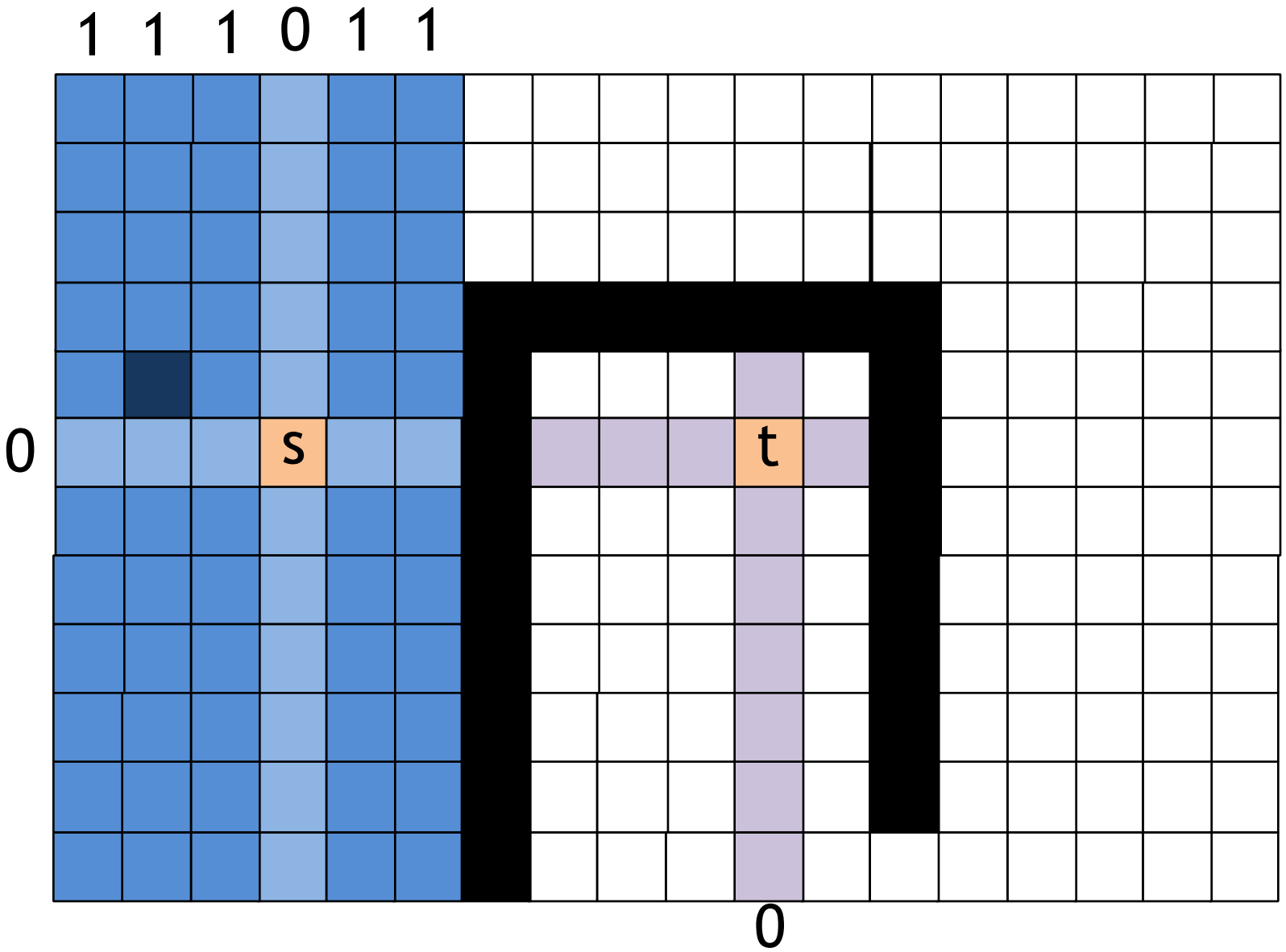
Source Line Probe (Level 1)



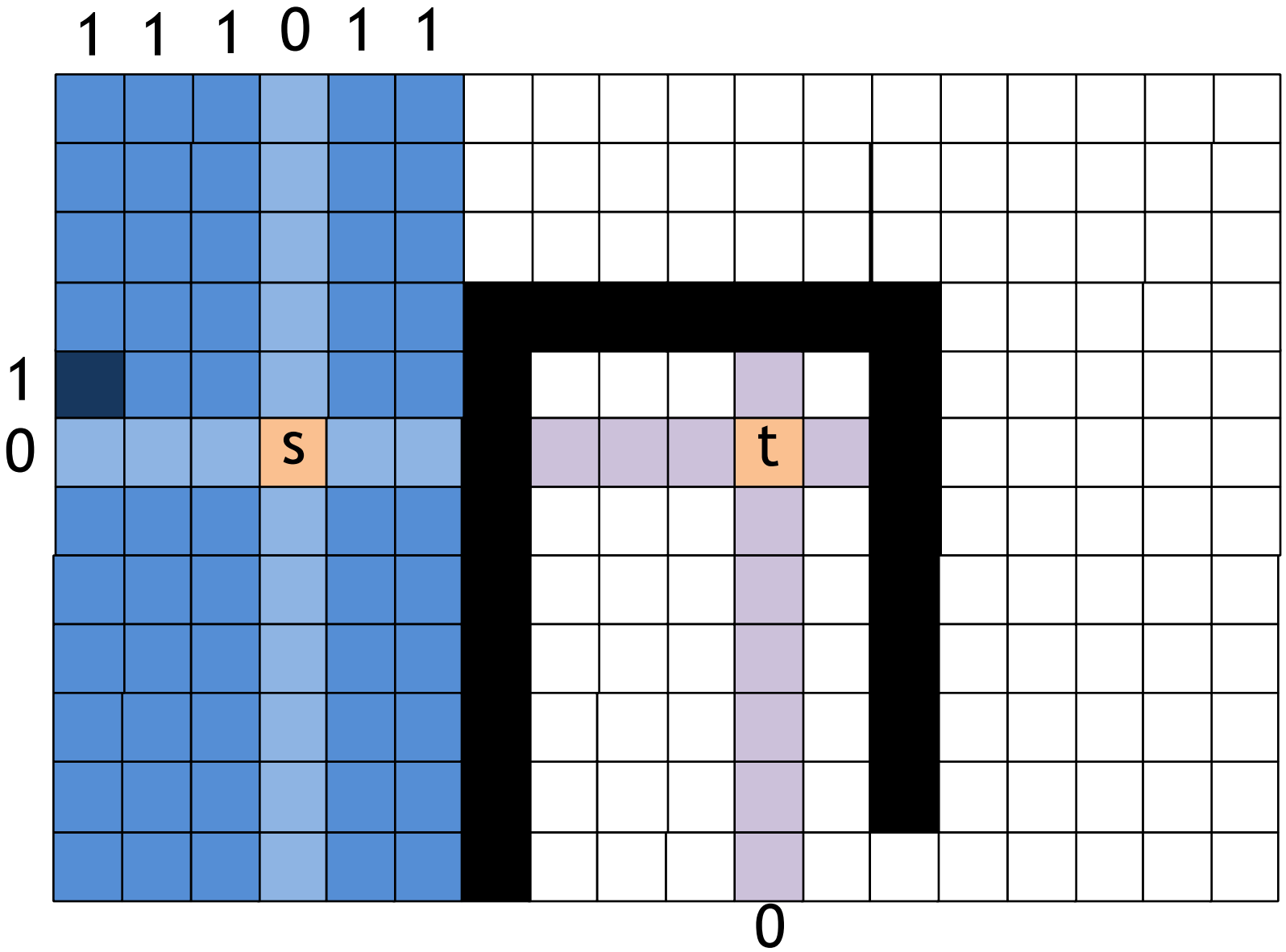
Source Line Probe (Level 1)



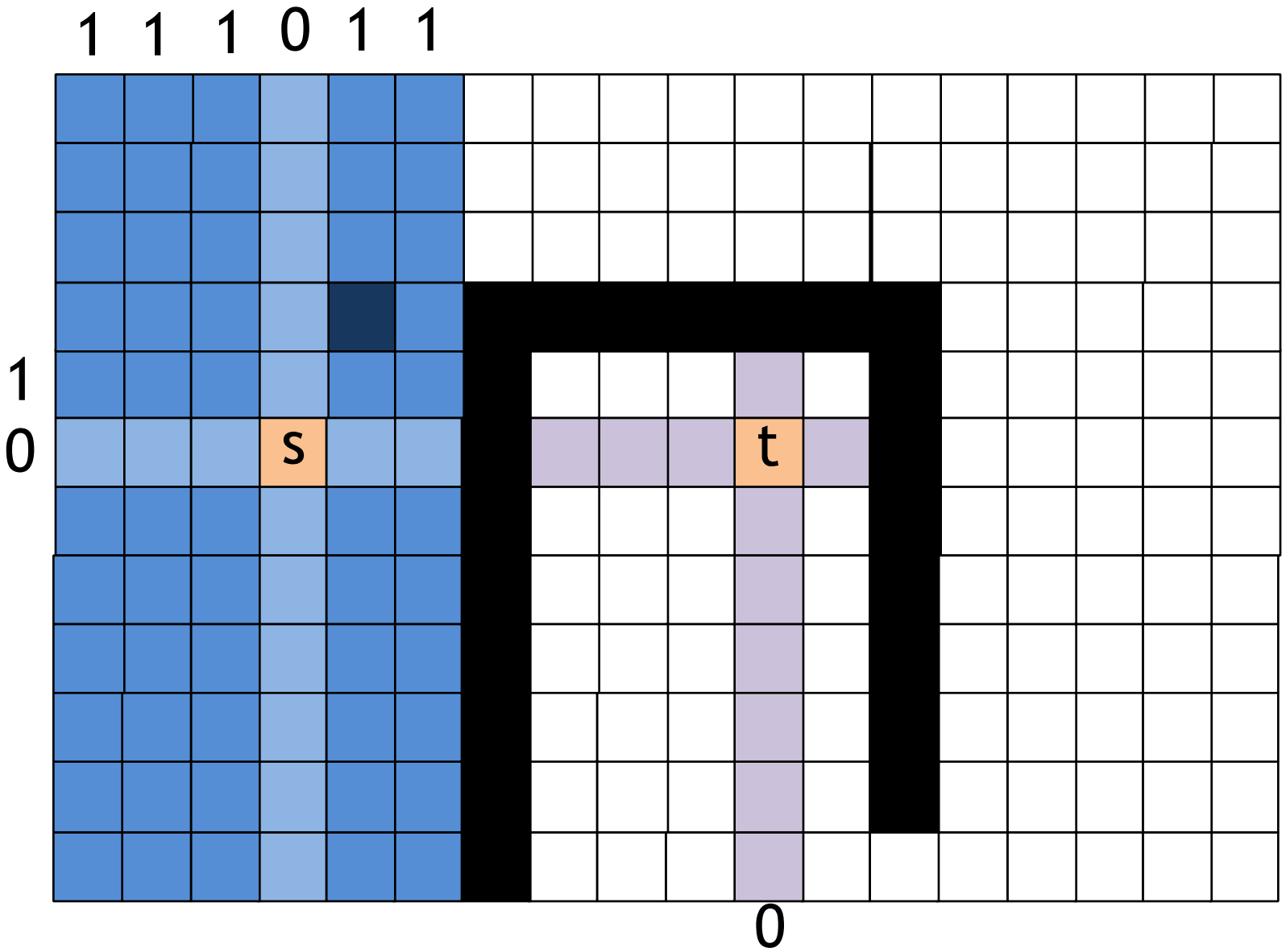
Source Line Probe (Level 1)



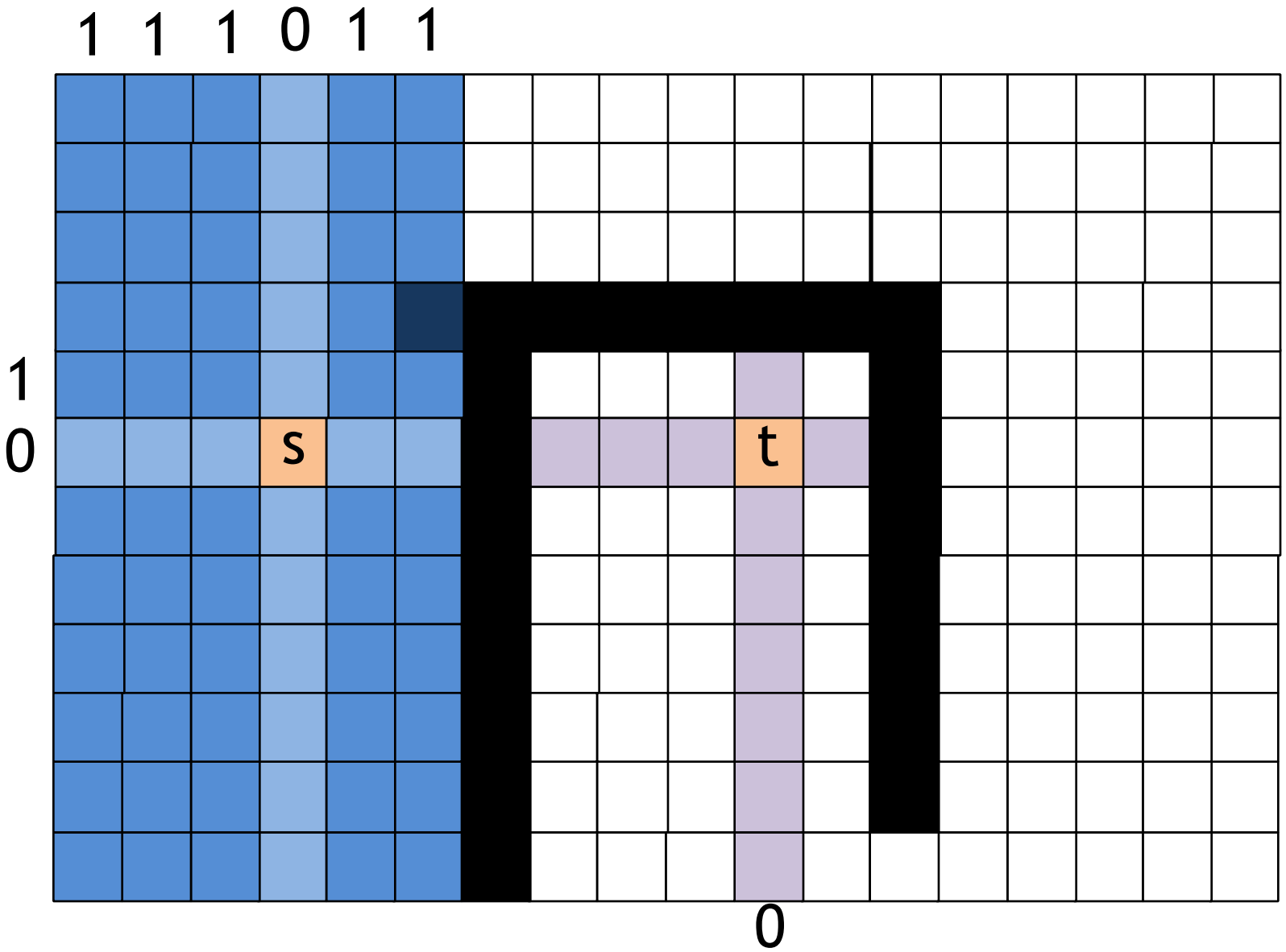
Source Line Probe (Level 1)



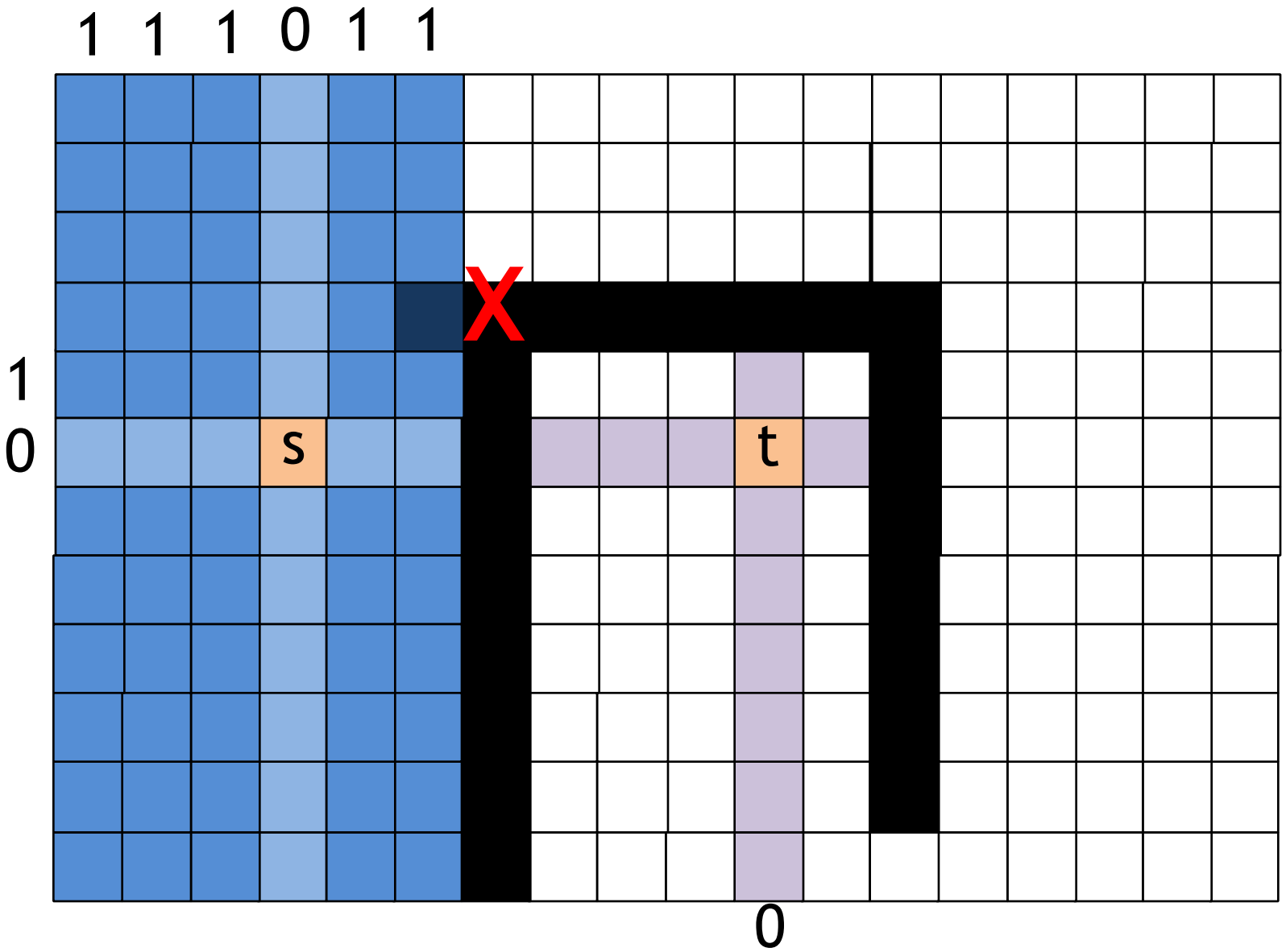
Source Line Probe (Level 1)



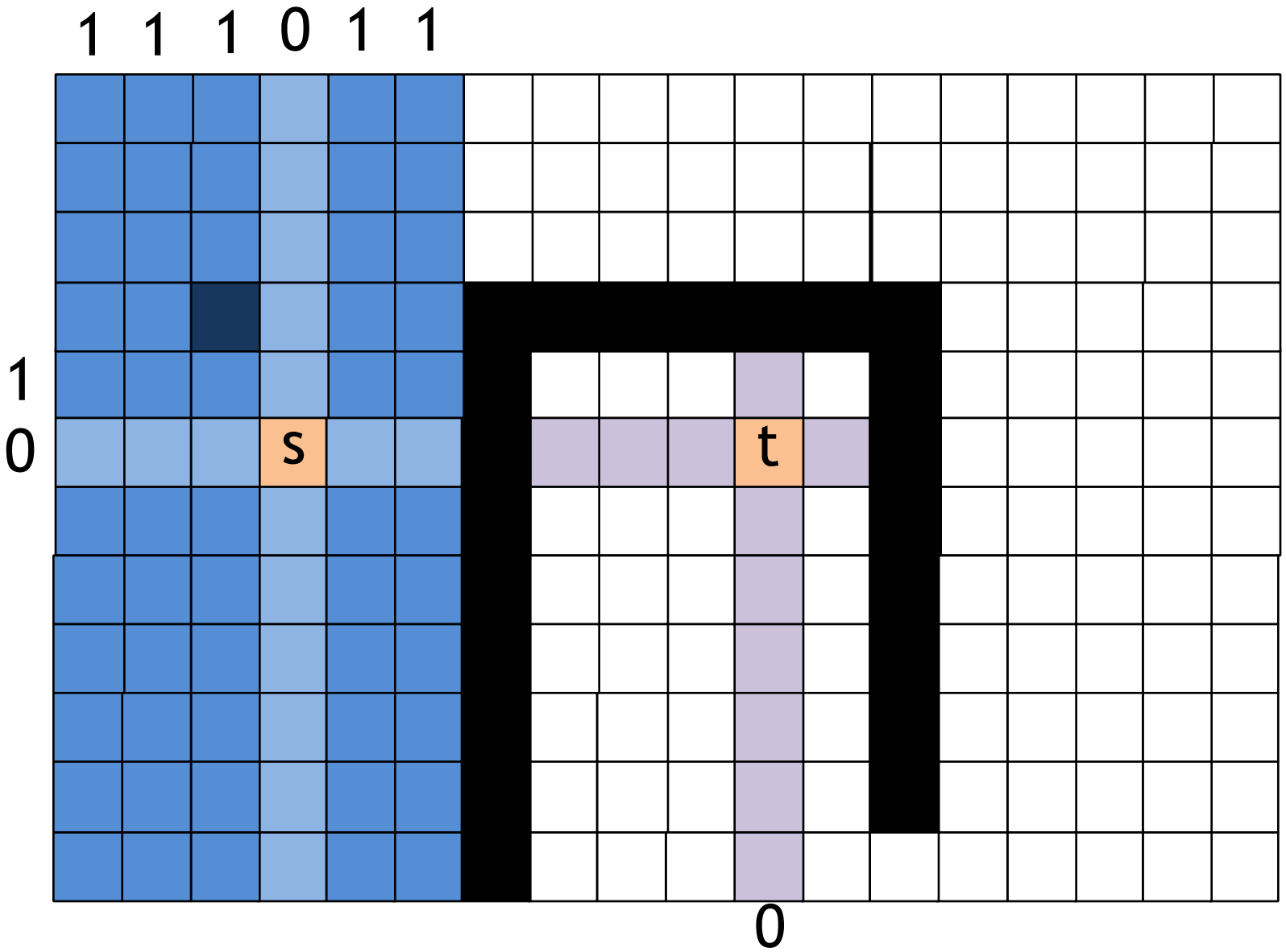
Source Line Probe (Level 1)



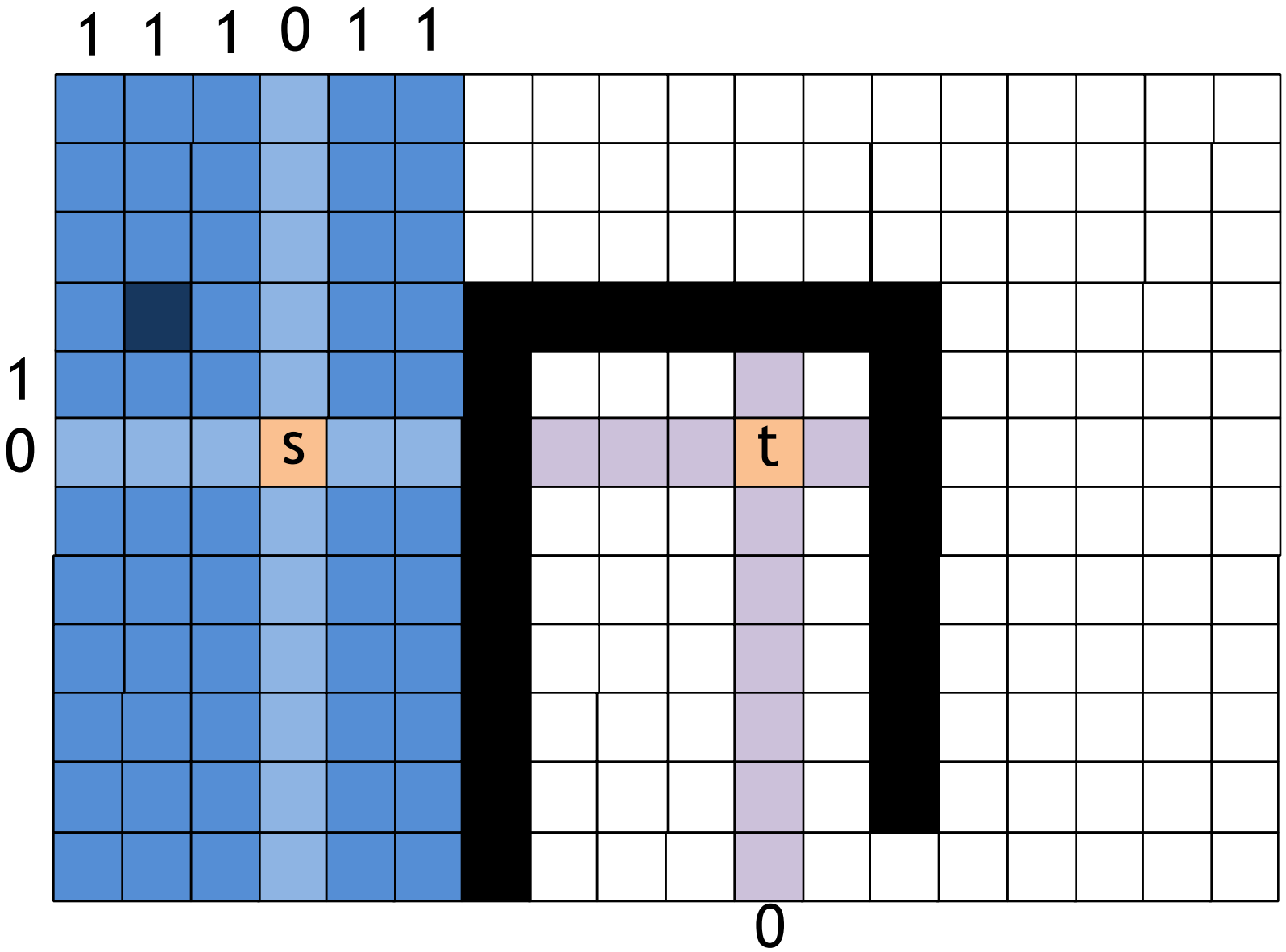
Source Line Probe (Level 1)



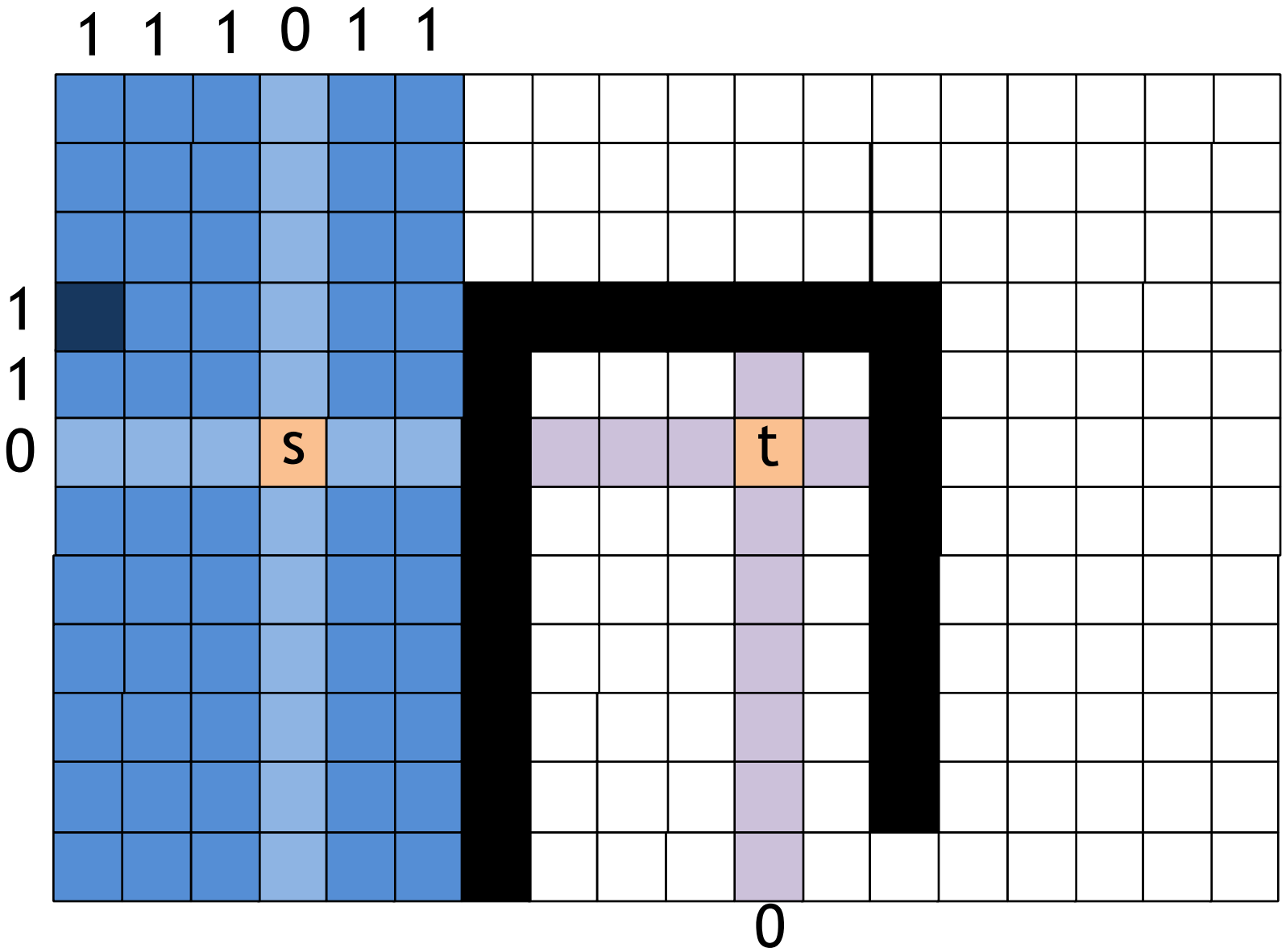
Source Line Probe (Level 1)



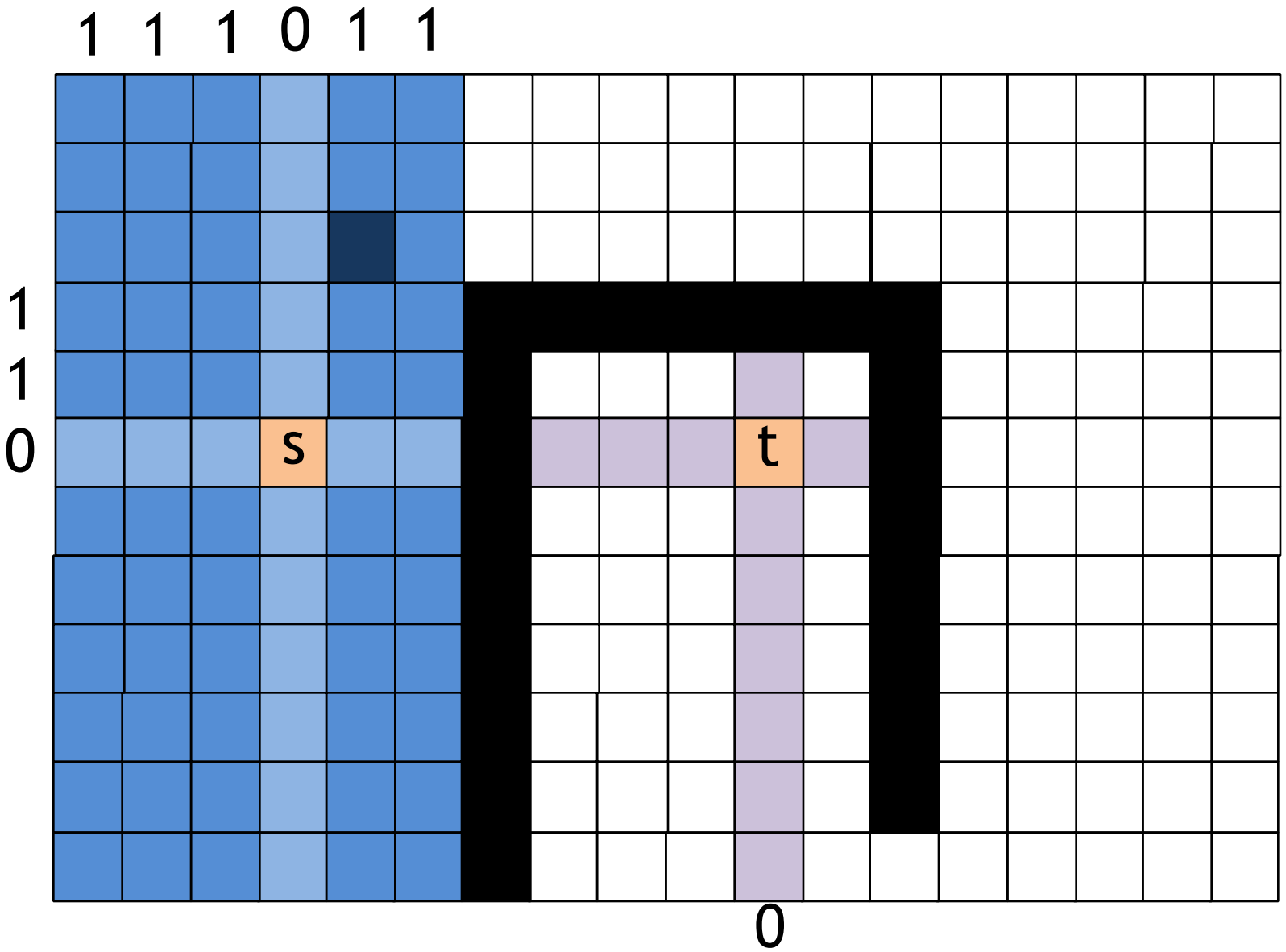
Source Line Probe (Level 1)



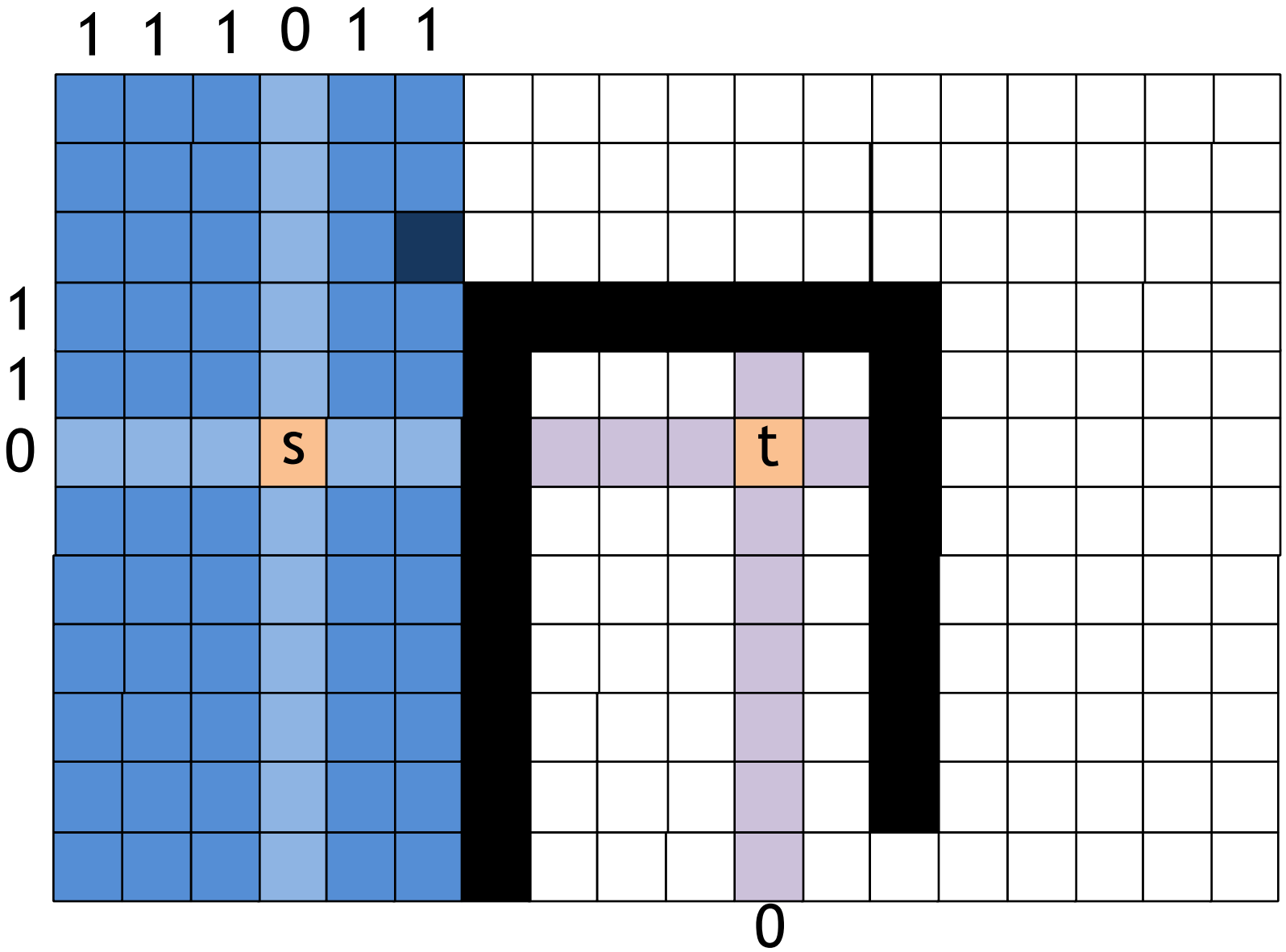
Source Line Probe (Level 1)



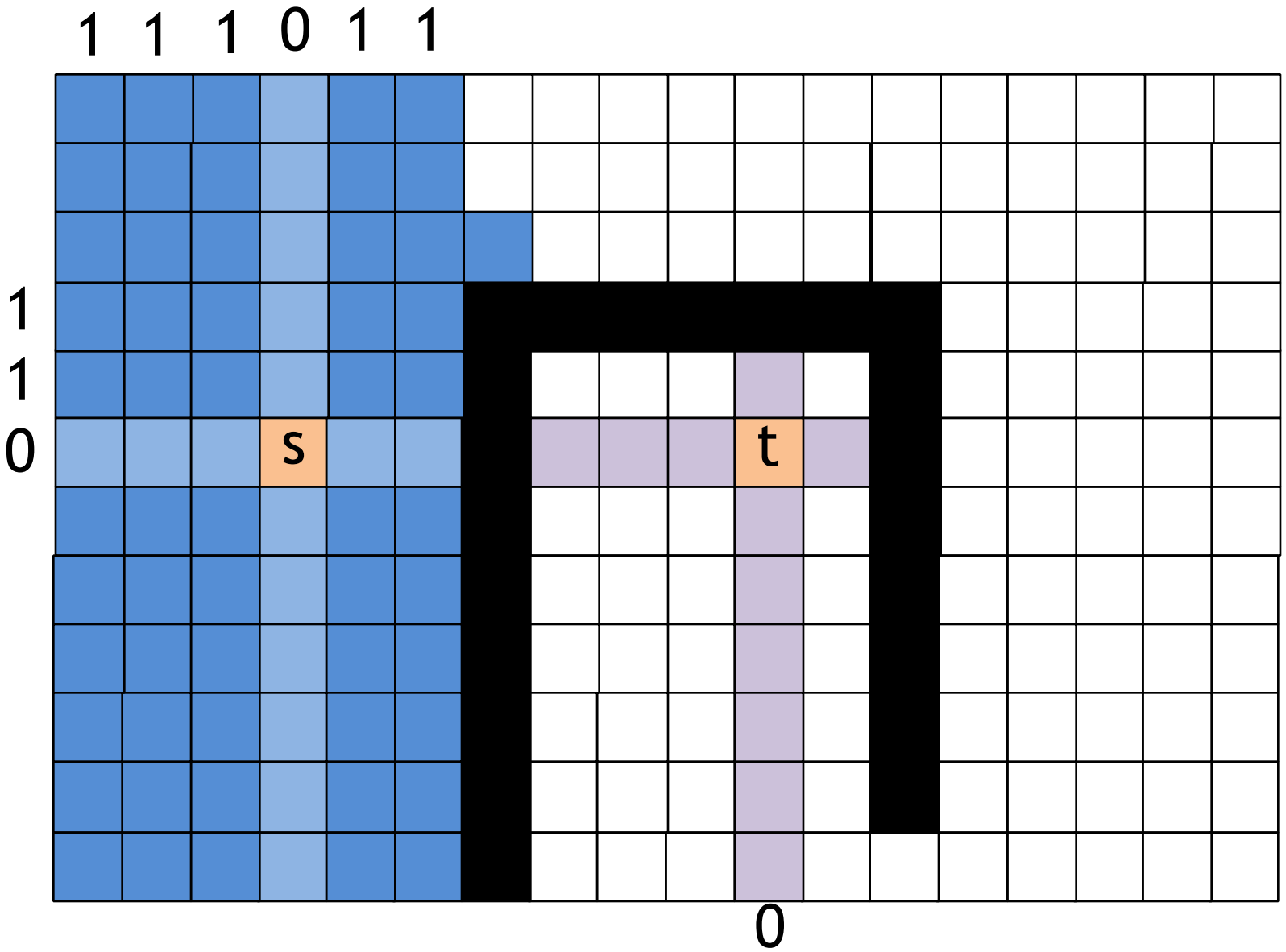
Source Line Probe (Level 1)



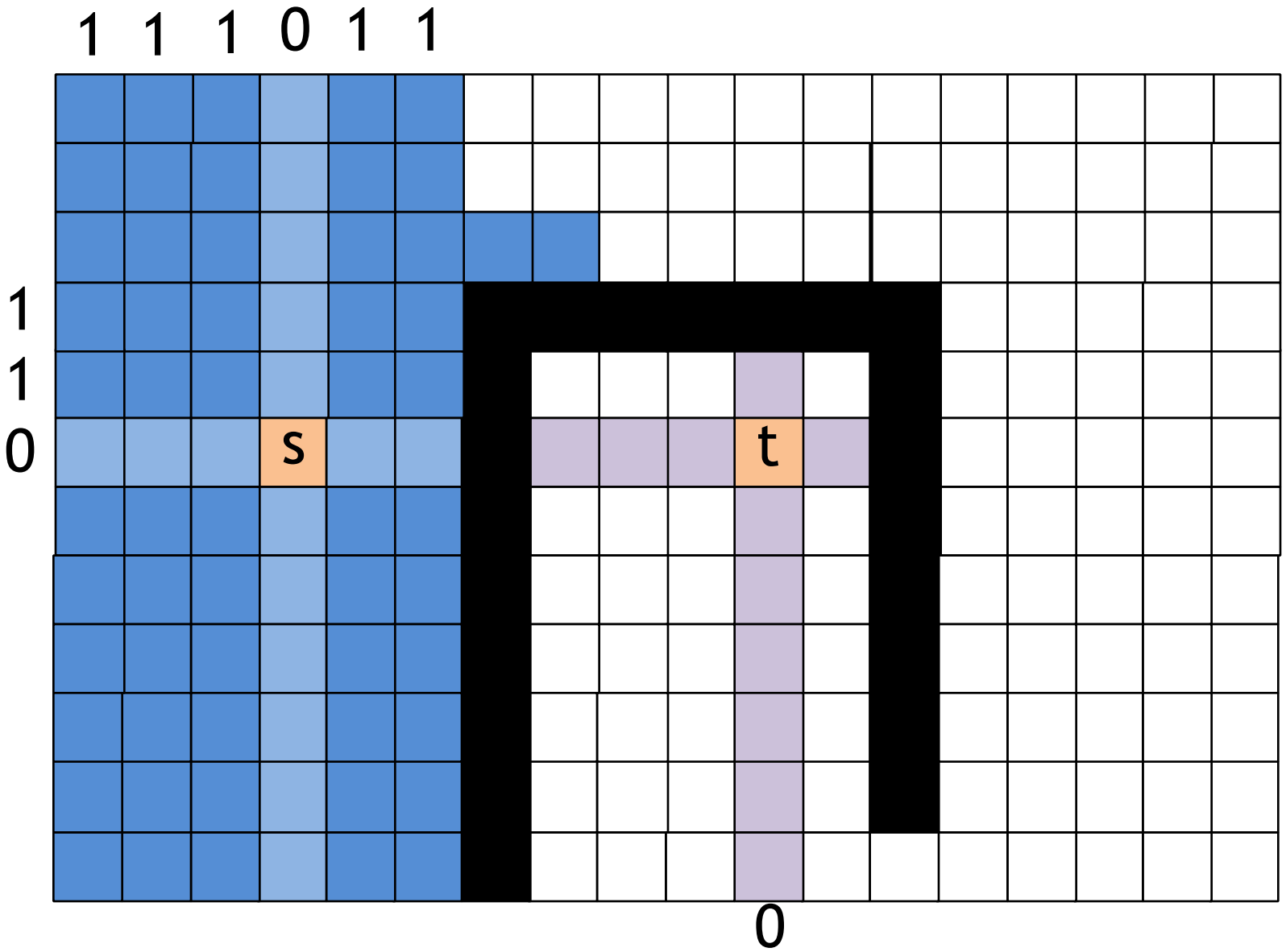
Source Line Probe (Level 1)



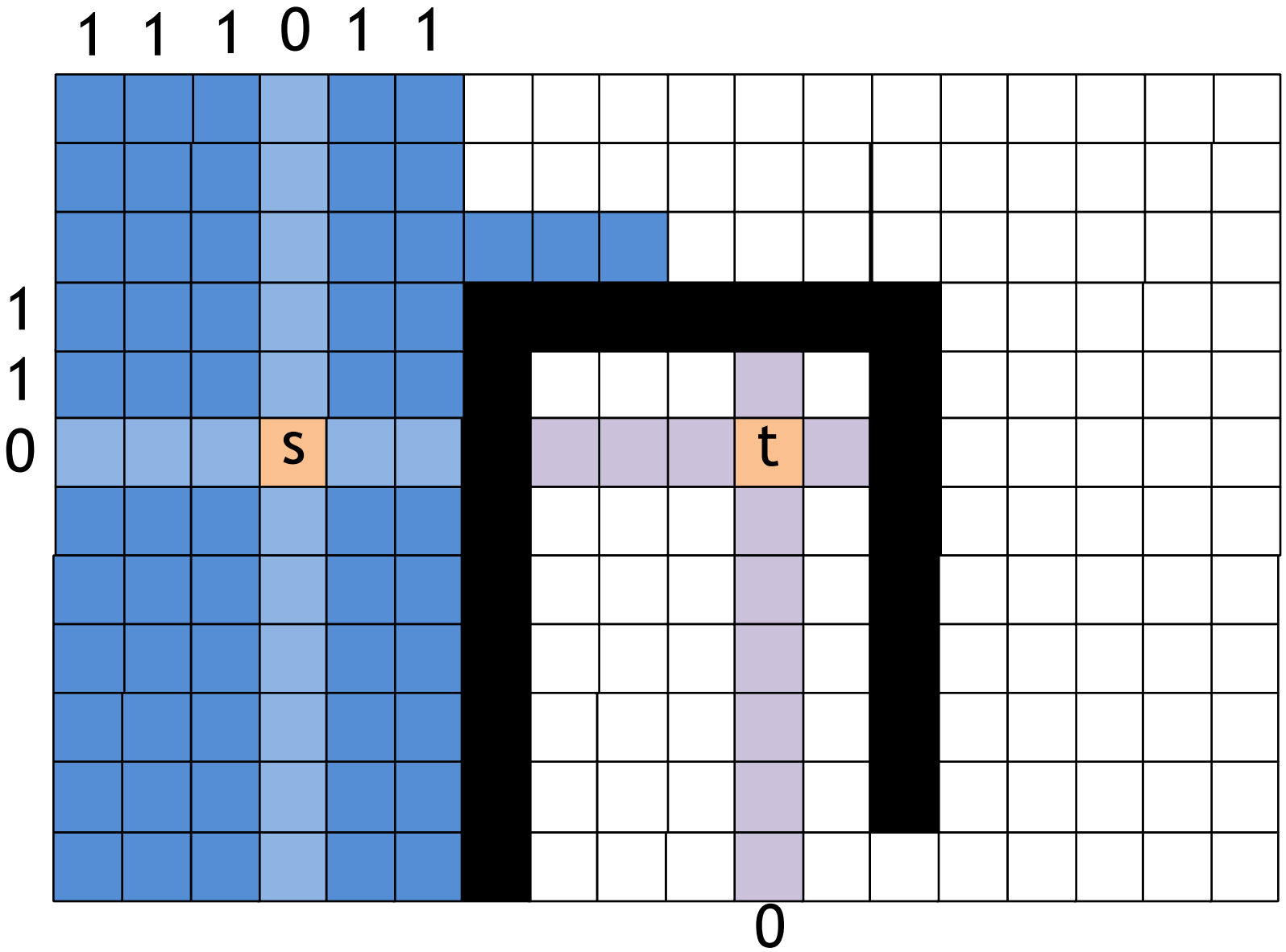
Source Line Probe (Level 1)



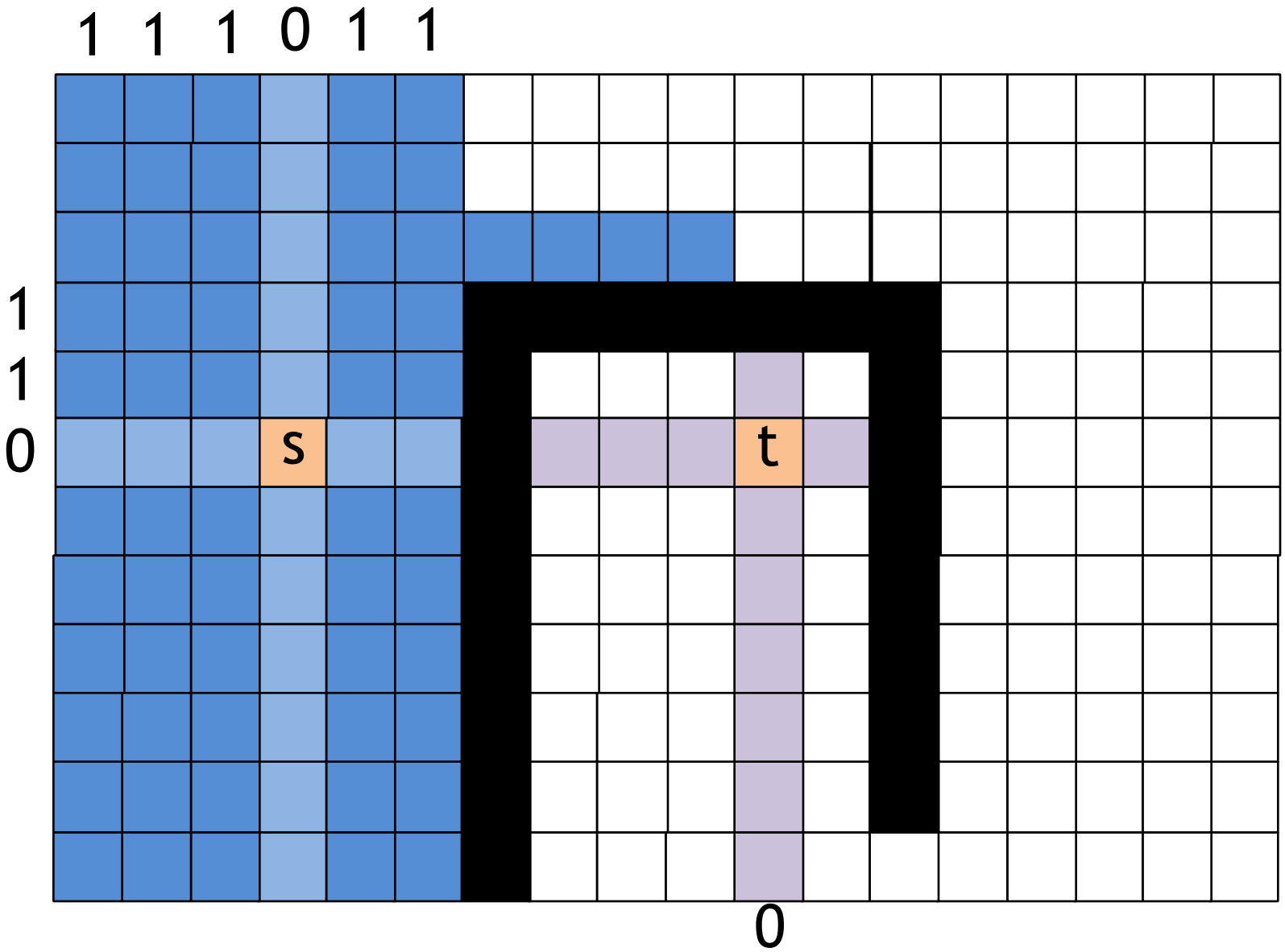
Source Line Probe (Level 1)



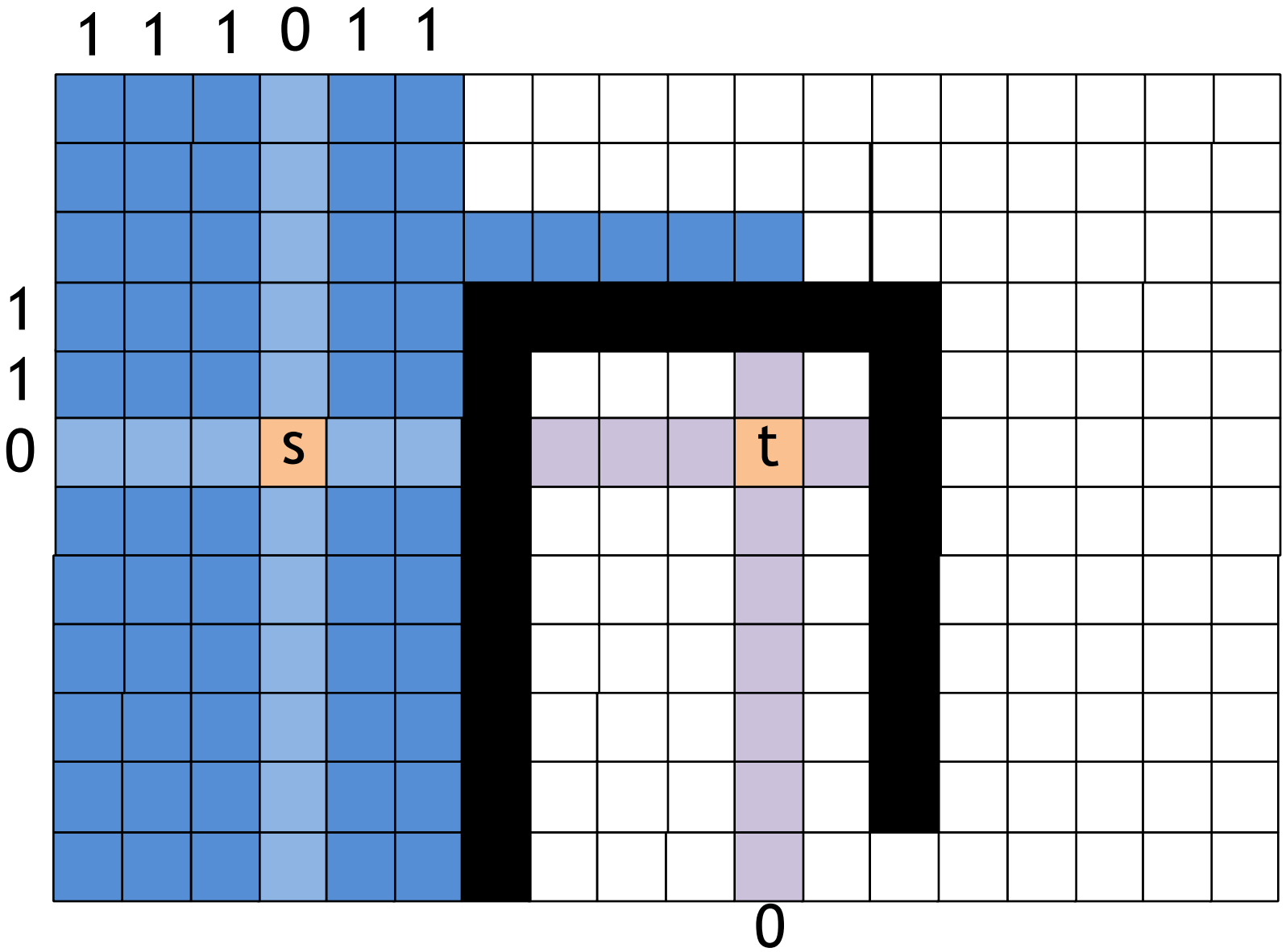
Source Line Probe (Level 1)



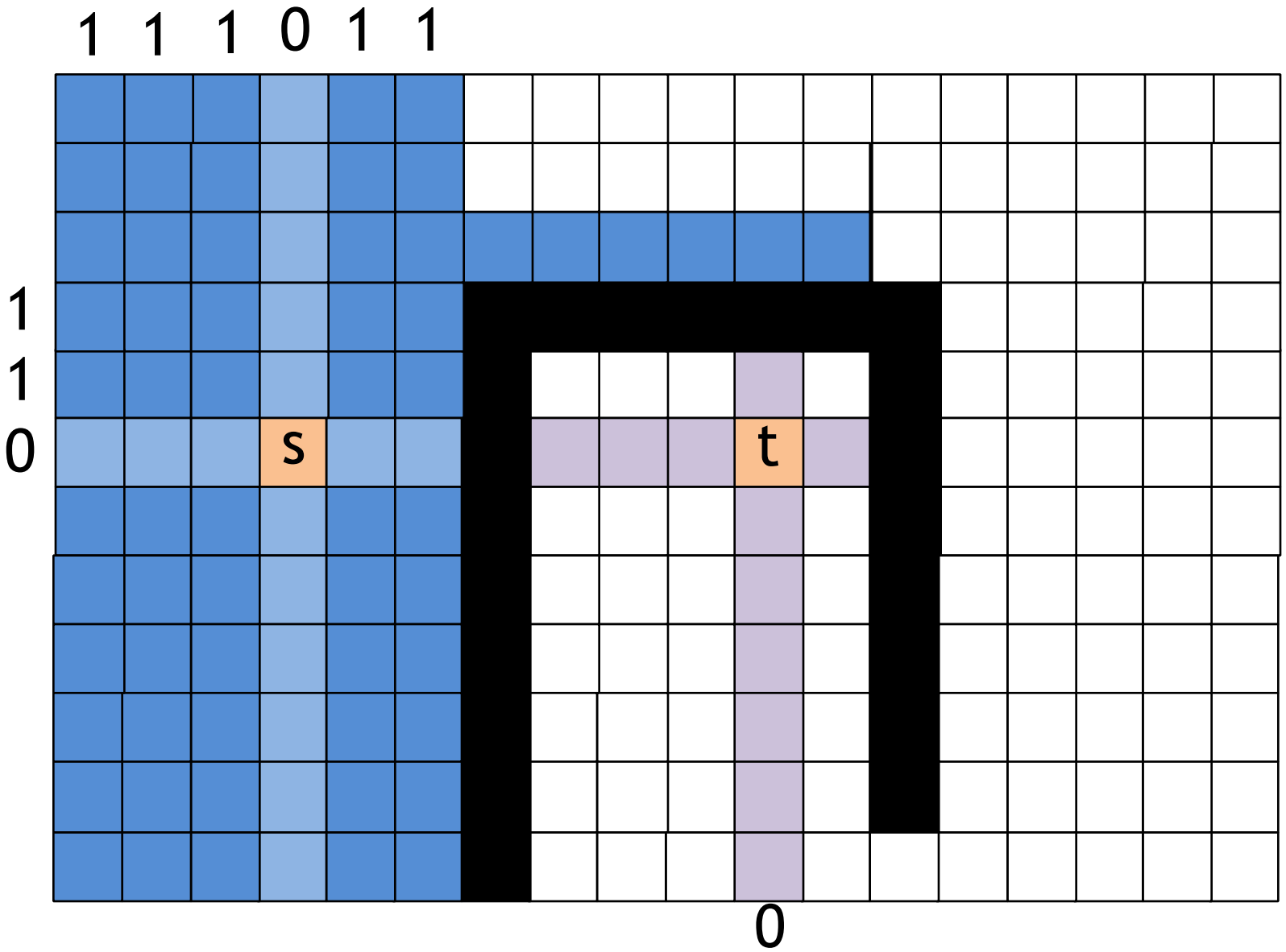
Source Line Probe (Level 1)



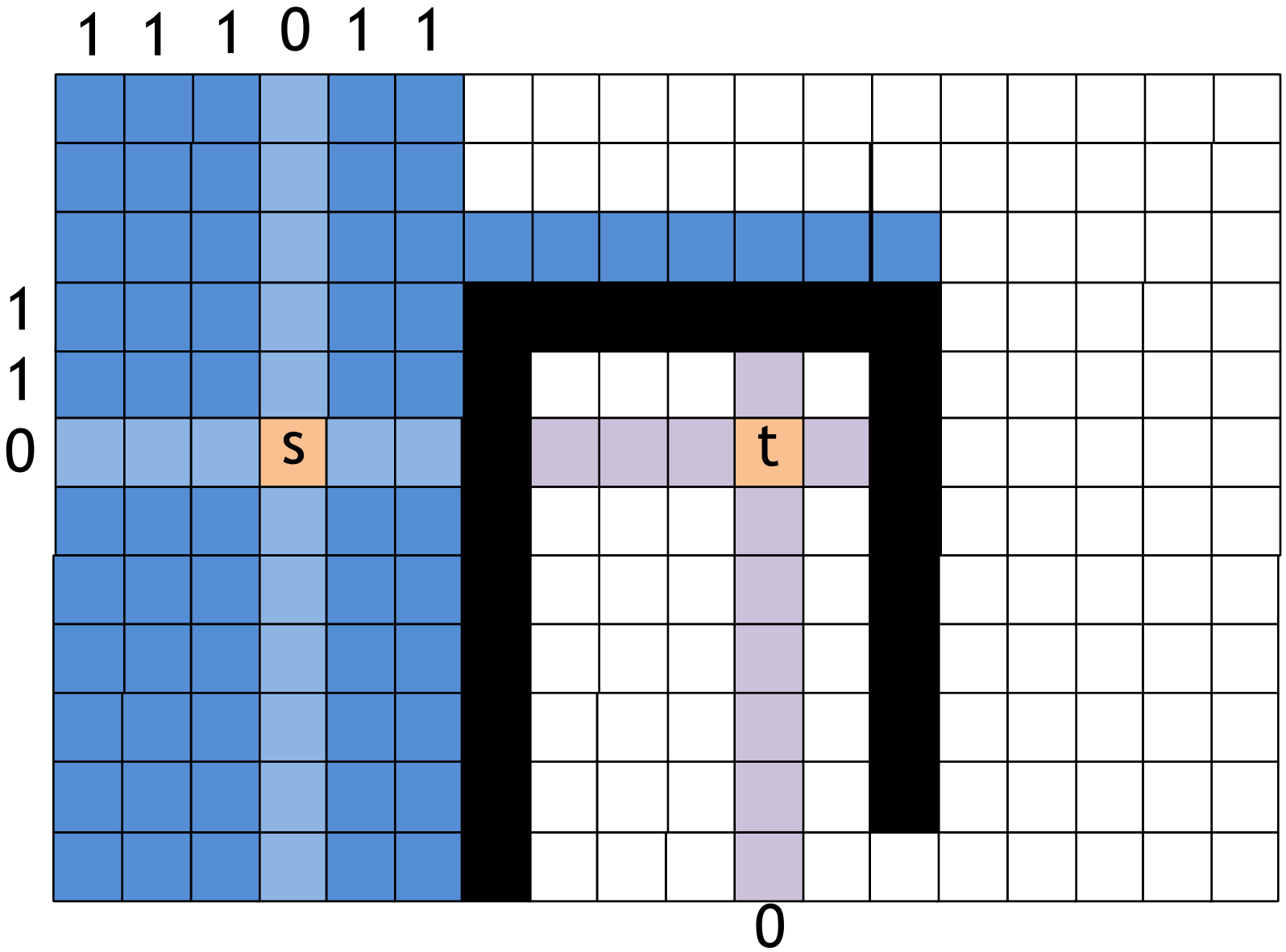
Source Line Probe (Level 1)



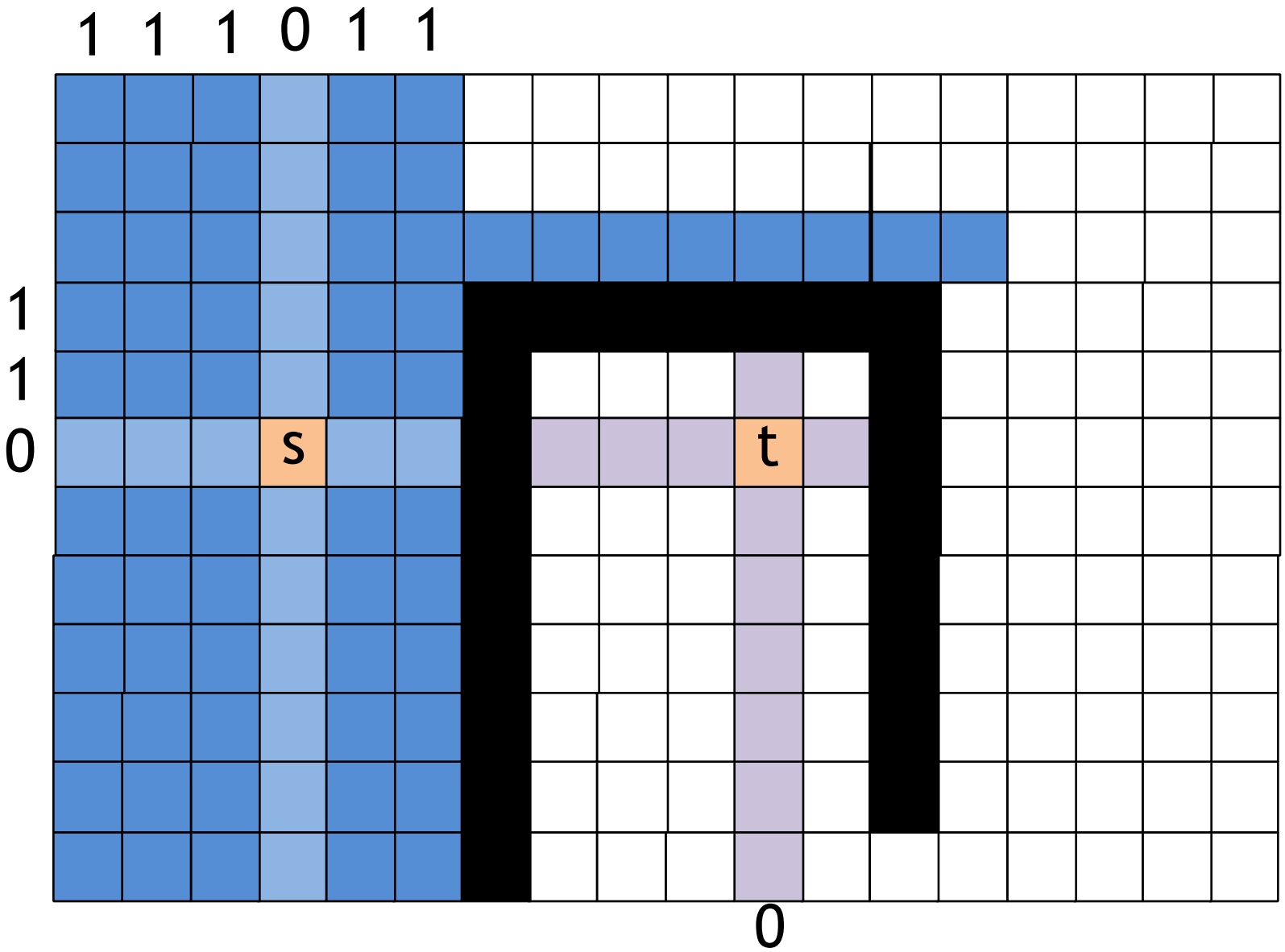
Source Line Probe (Level 1)



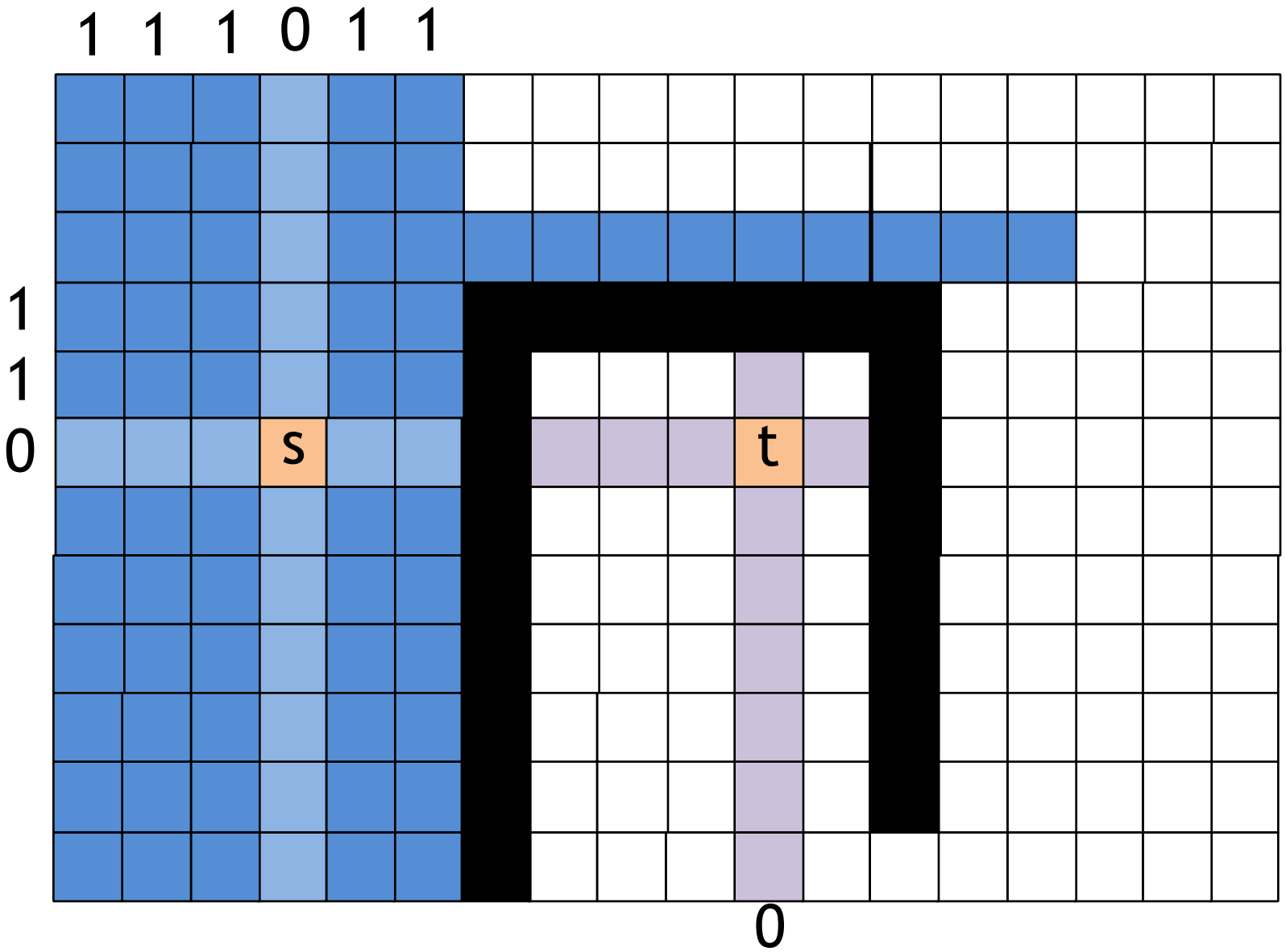
Source Line Probe (Level 1)



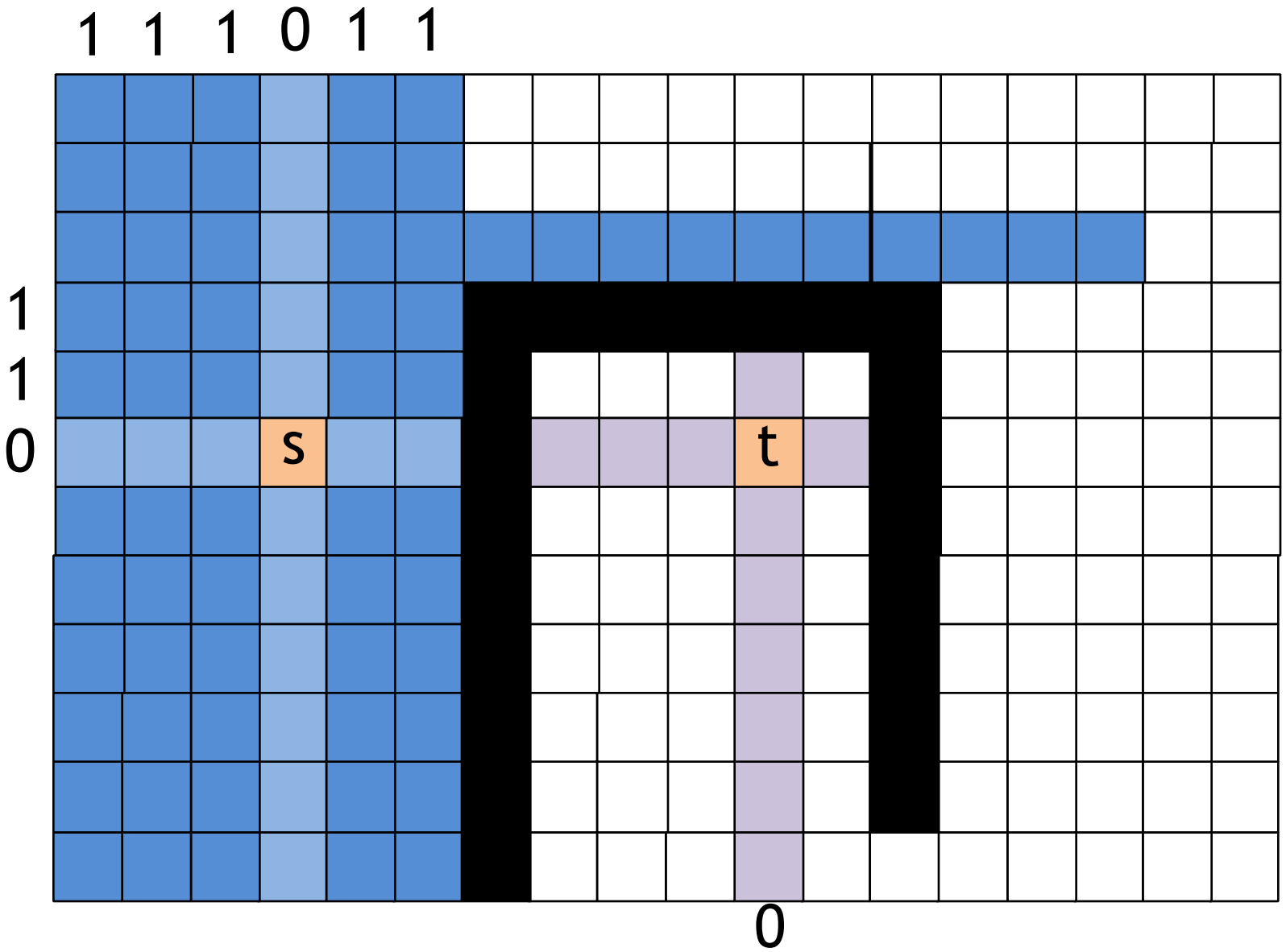
Source Line Probe (Level 1)



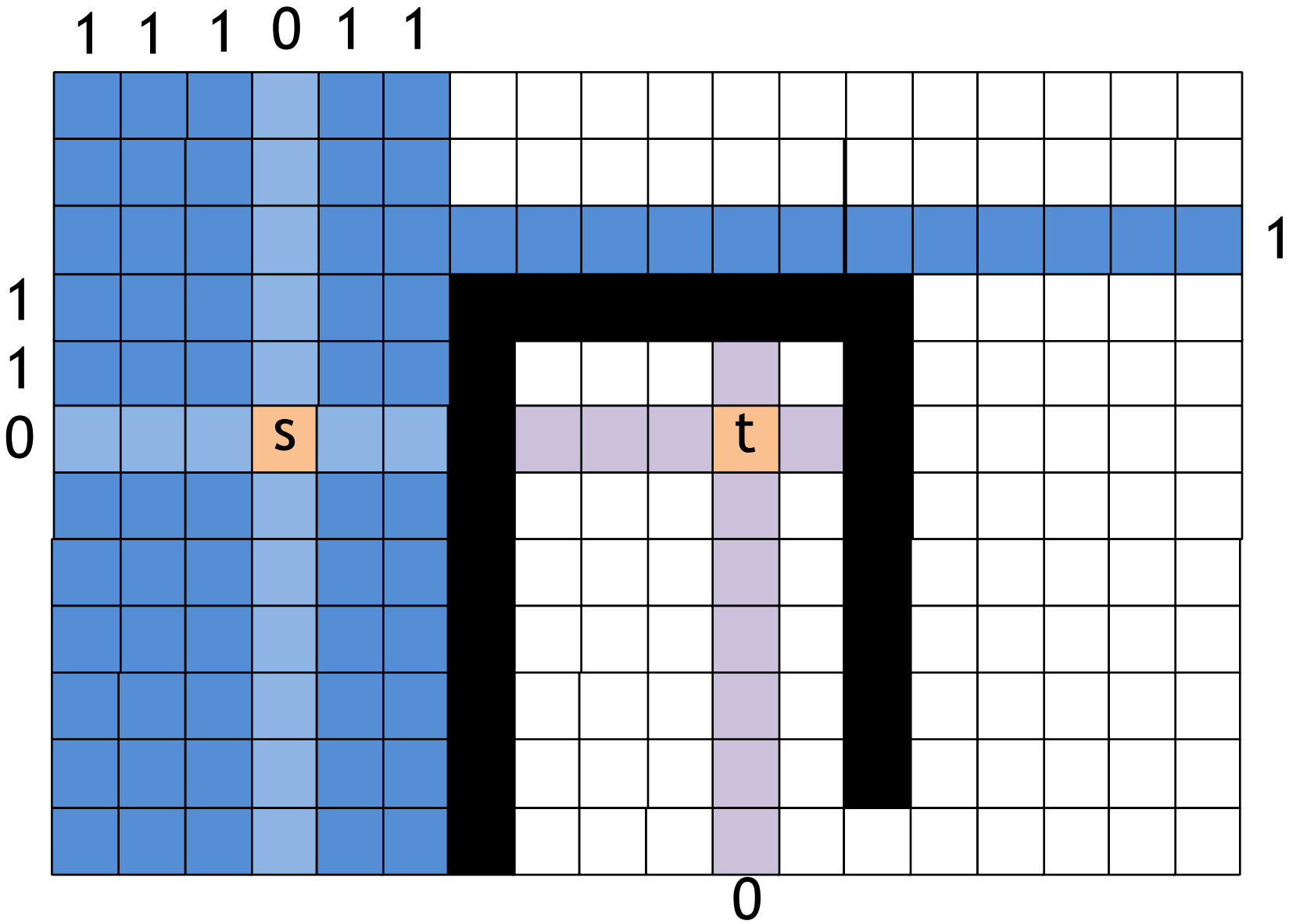
Source Line Probe (Level 1)



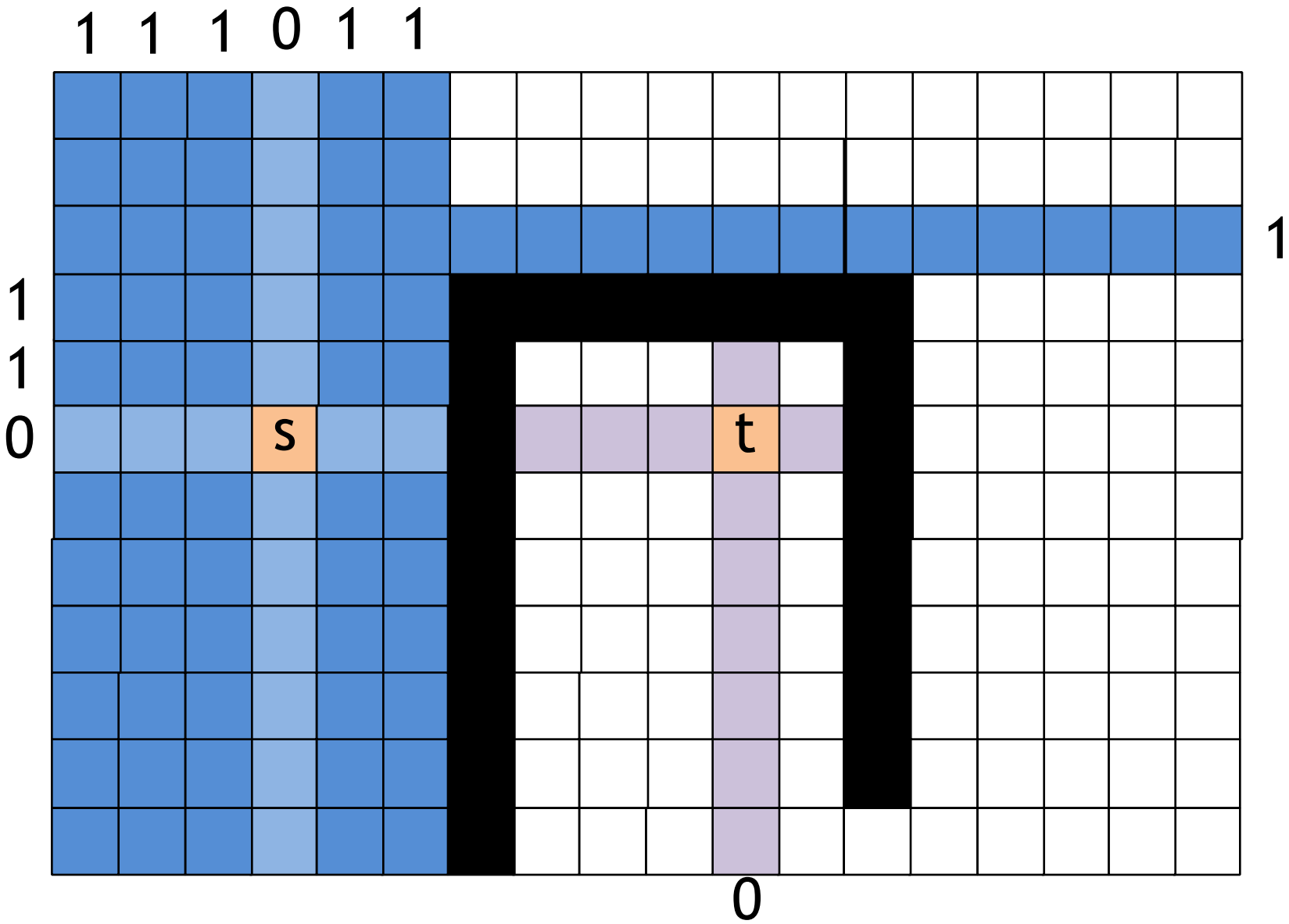
Source Line Probe (Level 1)



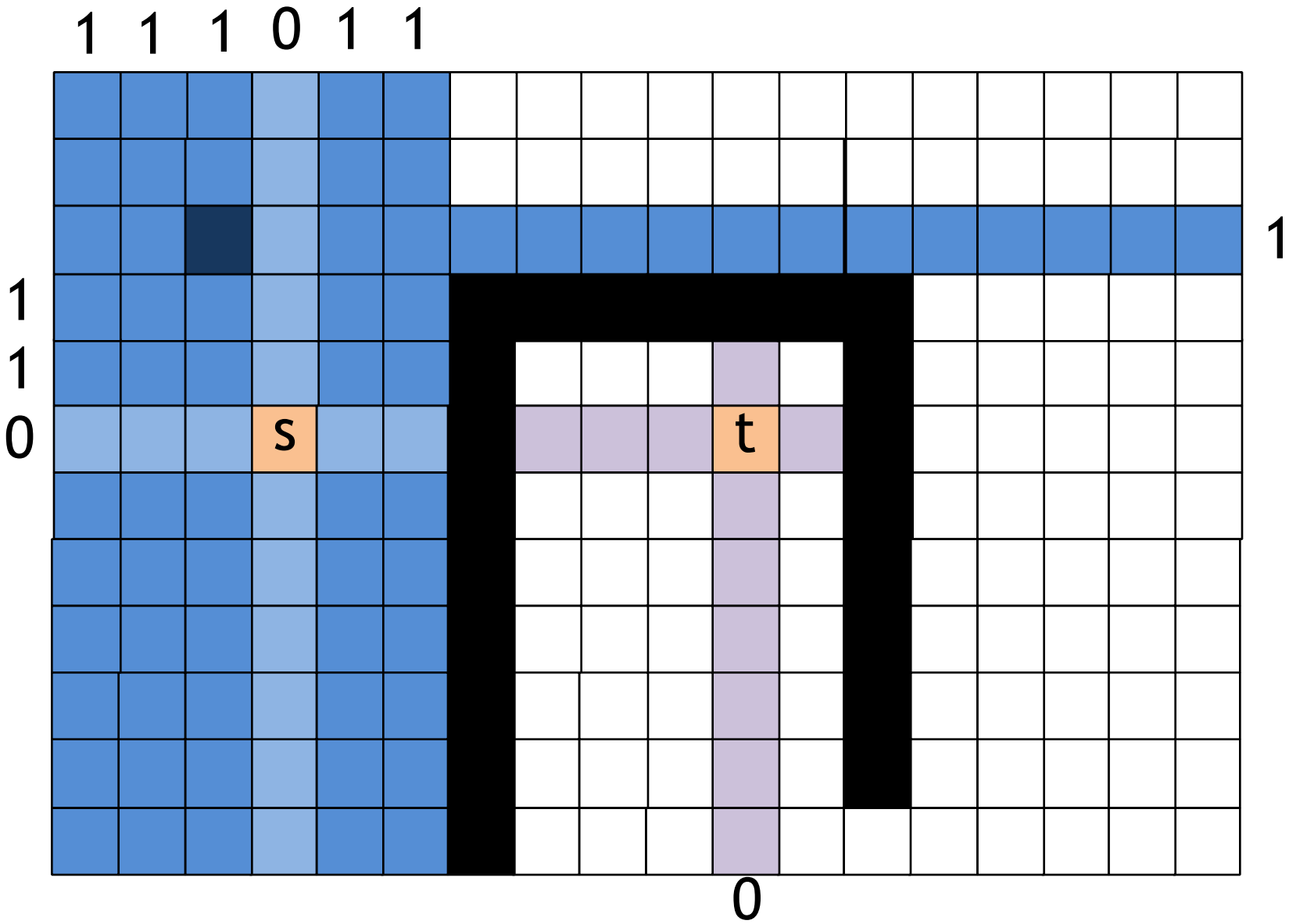
Source Line Probe (Level 1)



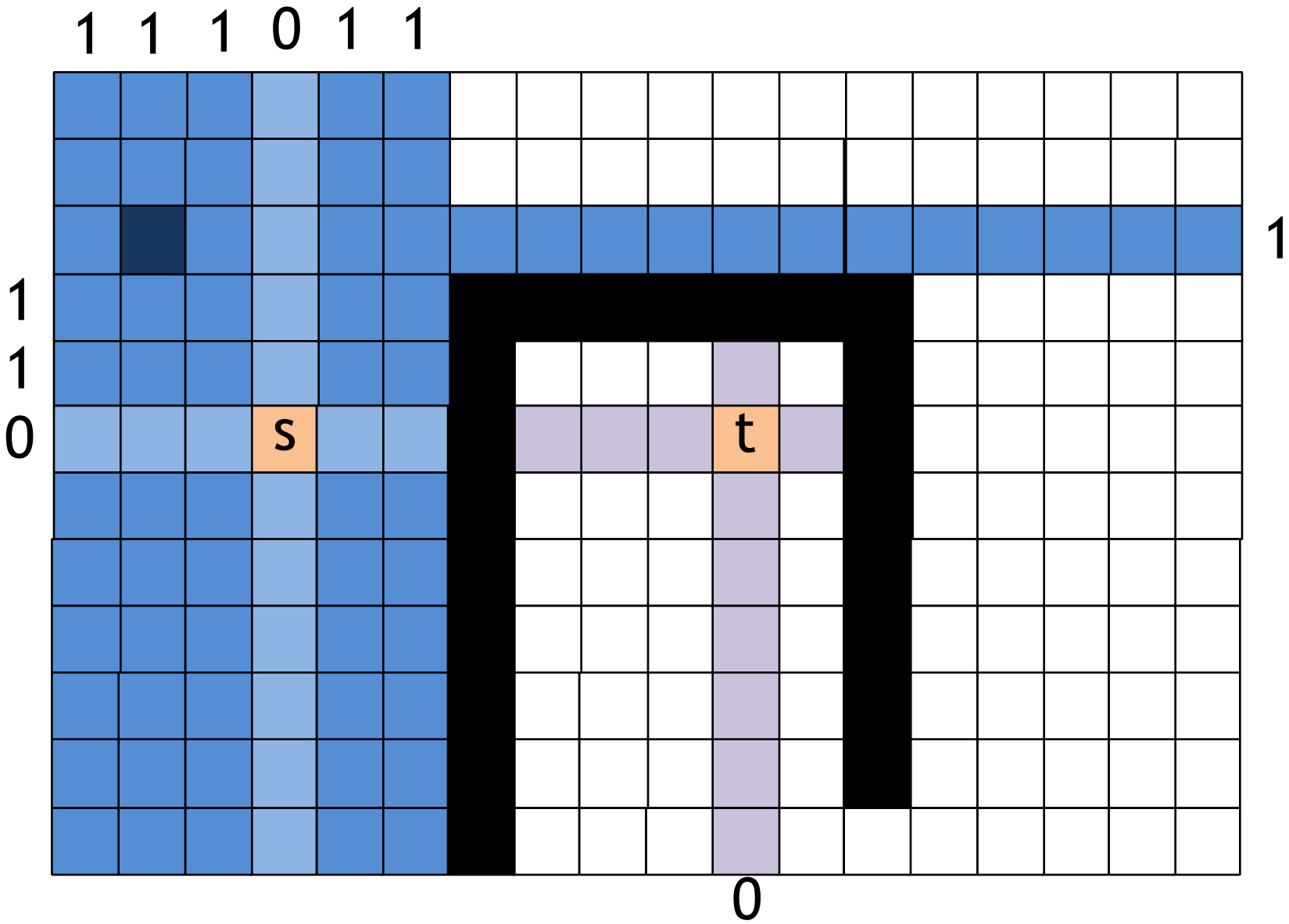
Source Line Probe (Level 1)



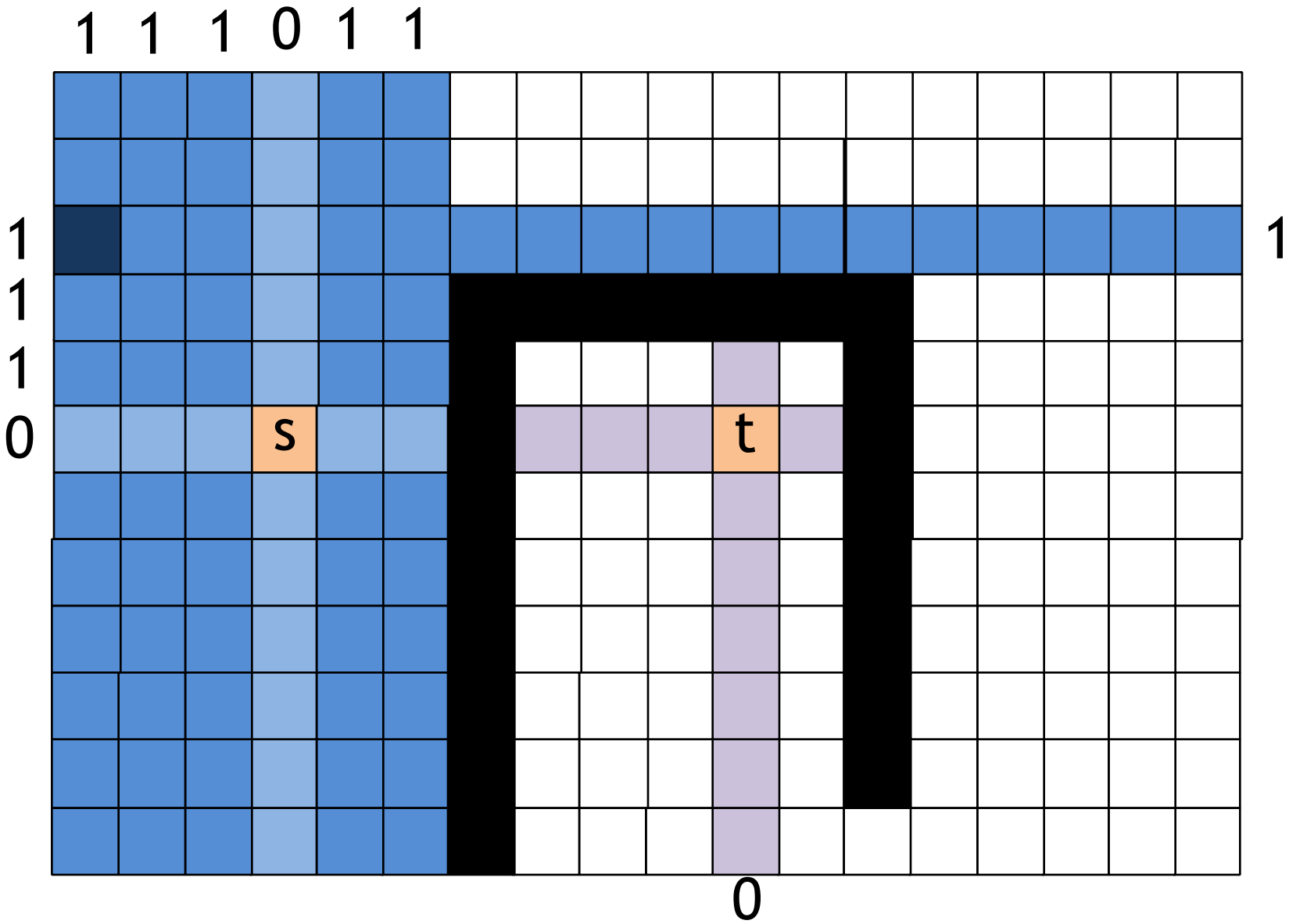
Source Line Probe (Level 1)



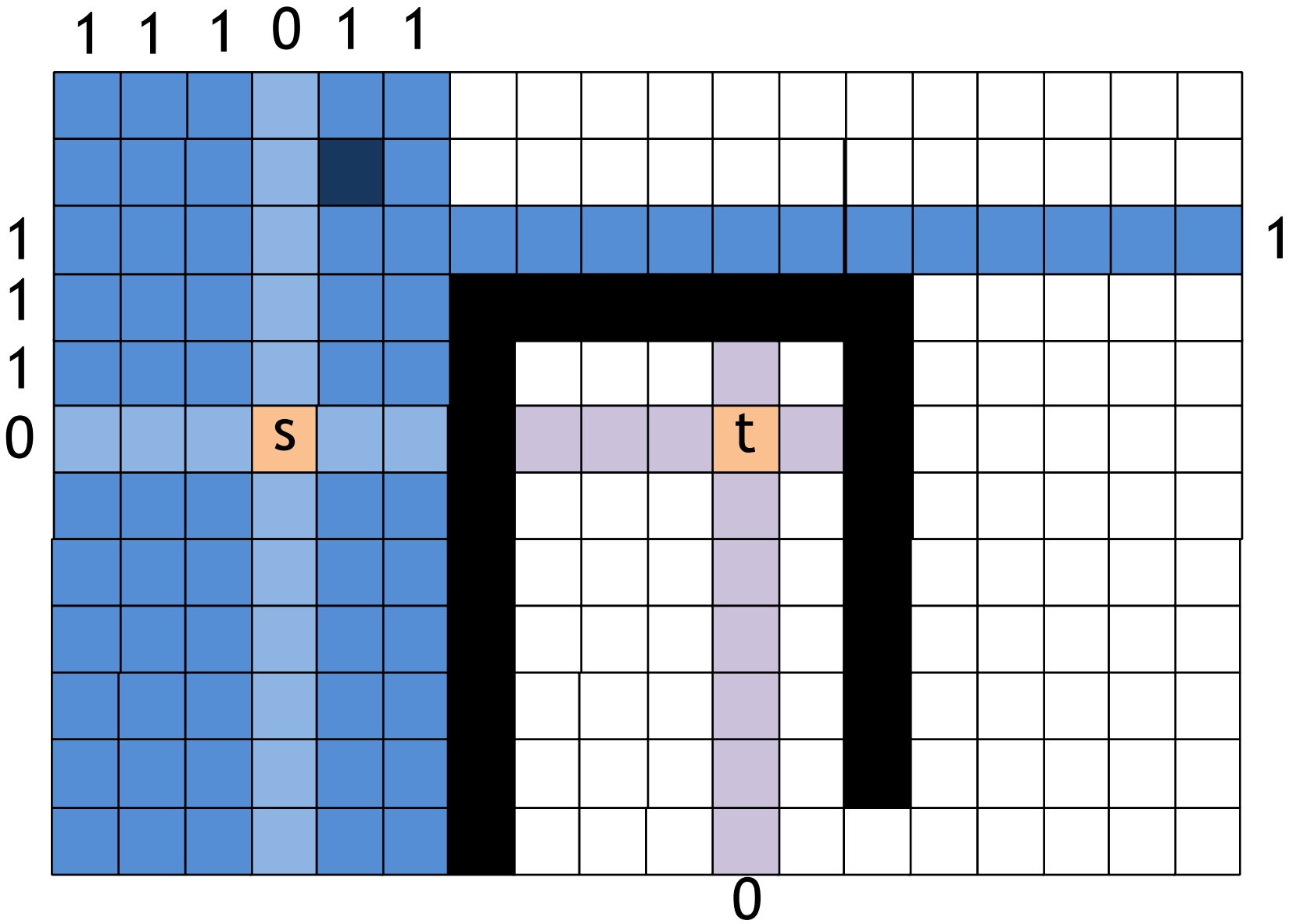
Source Line Probe (Level 1)



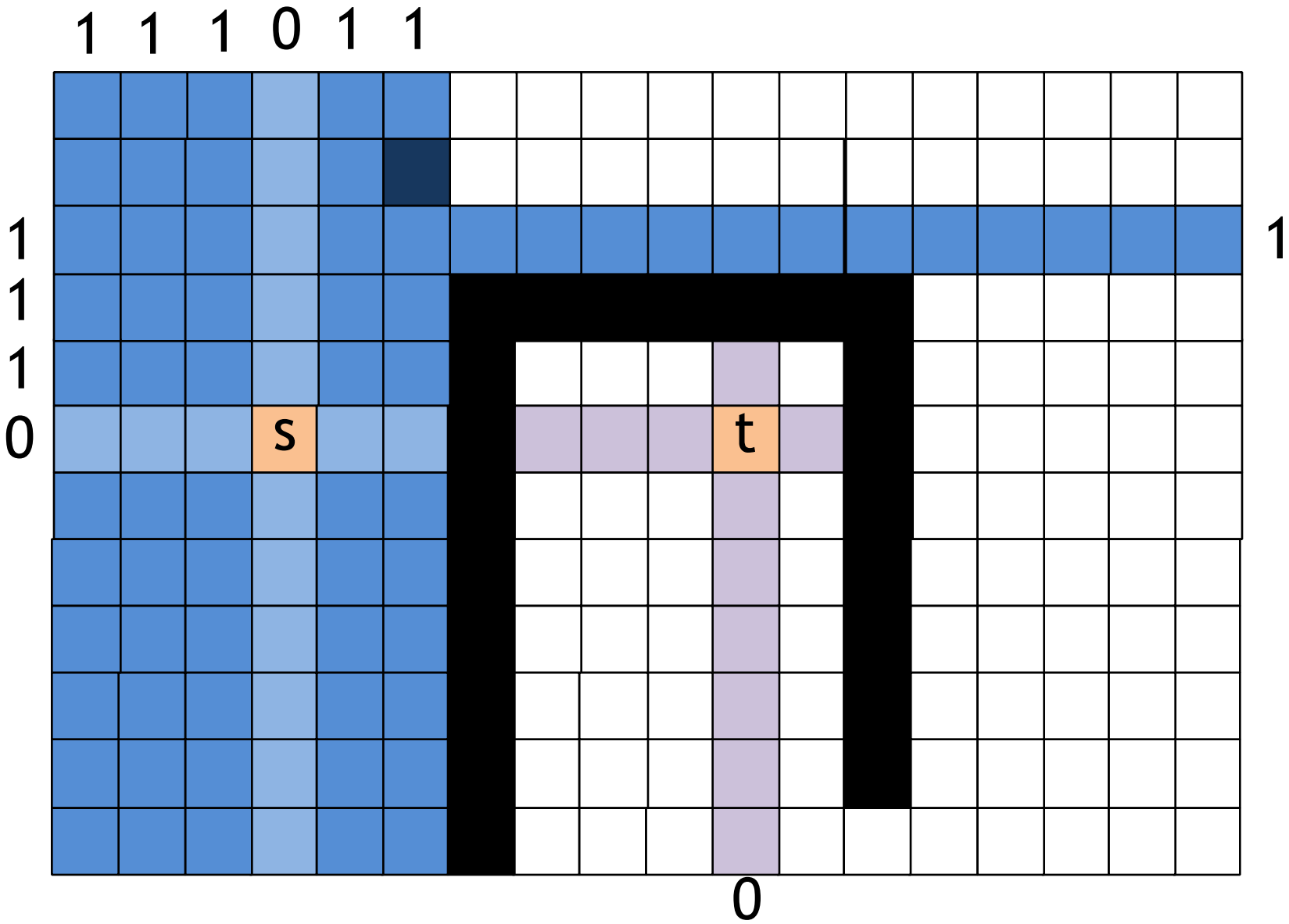
Source Line Probe (Level 1)



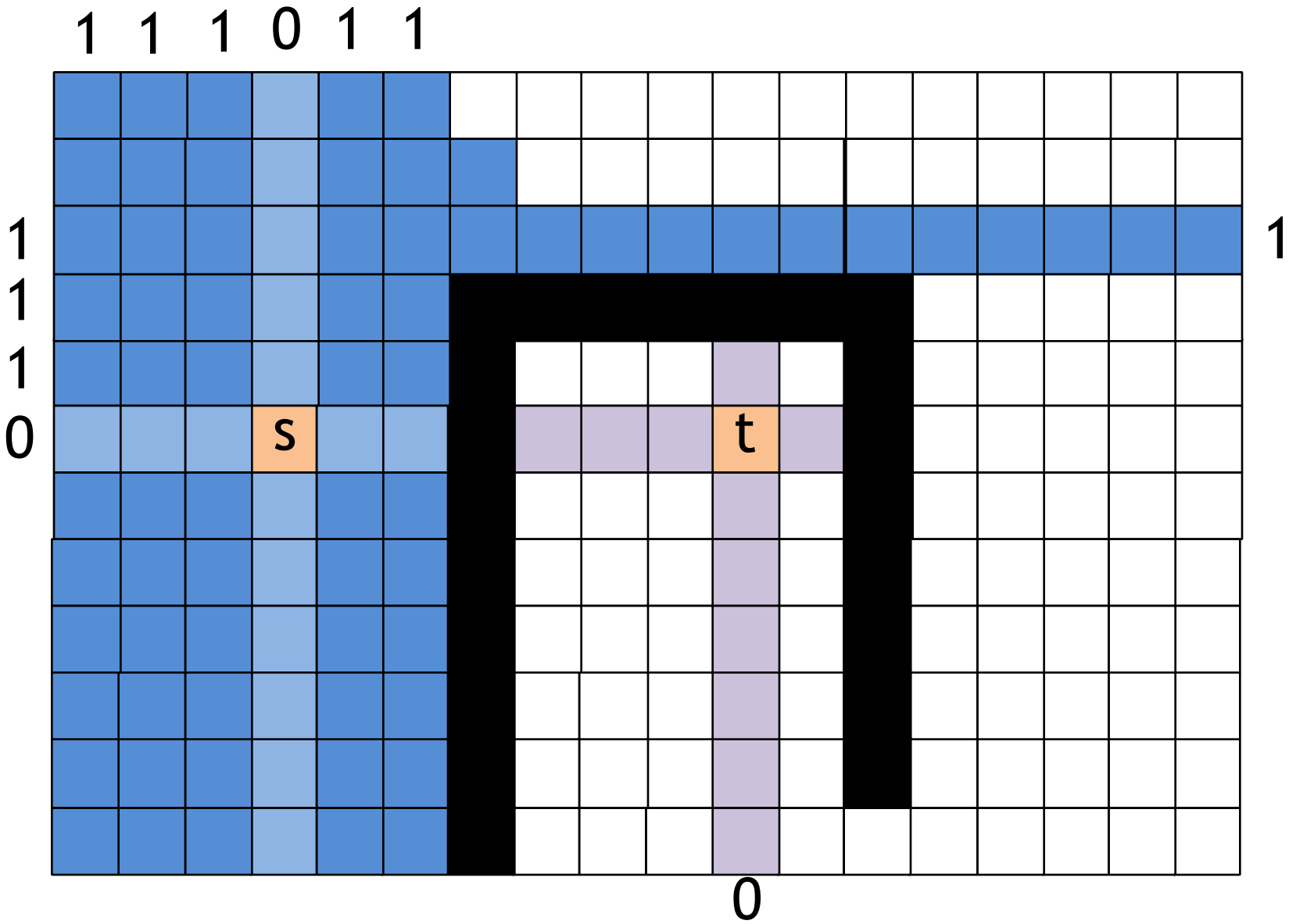
Source Line Probe (Level 1)



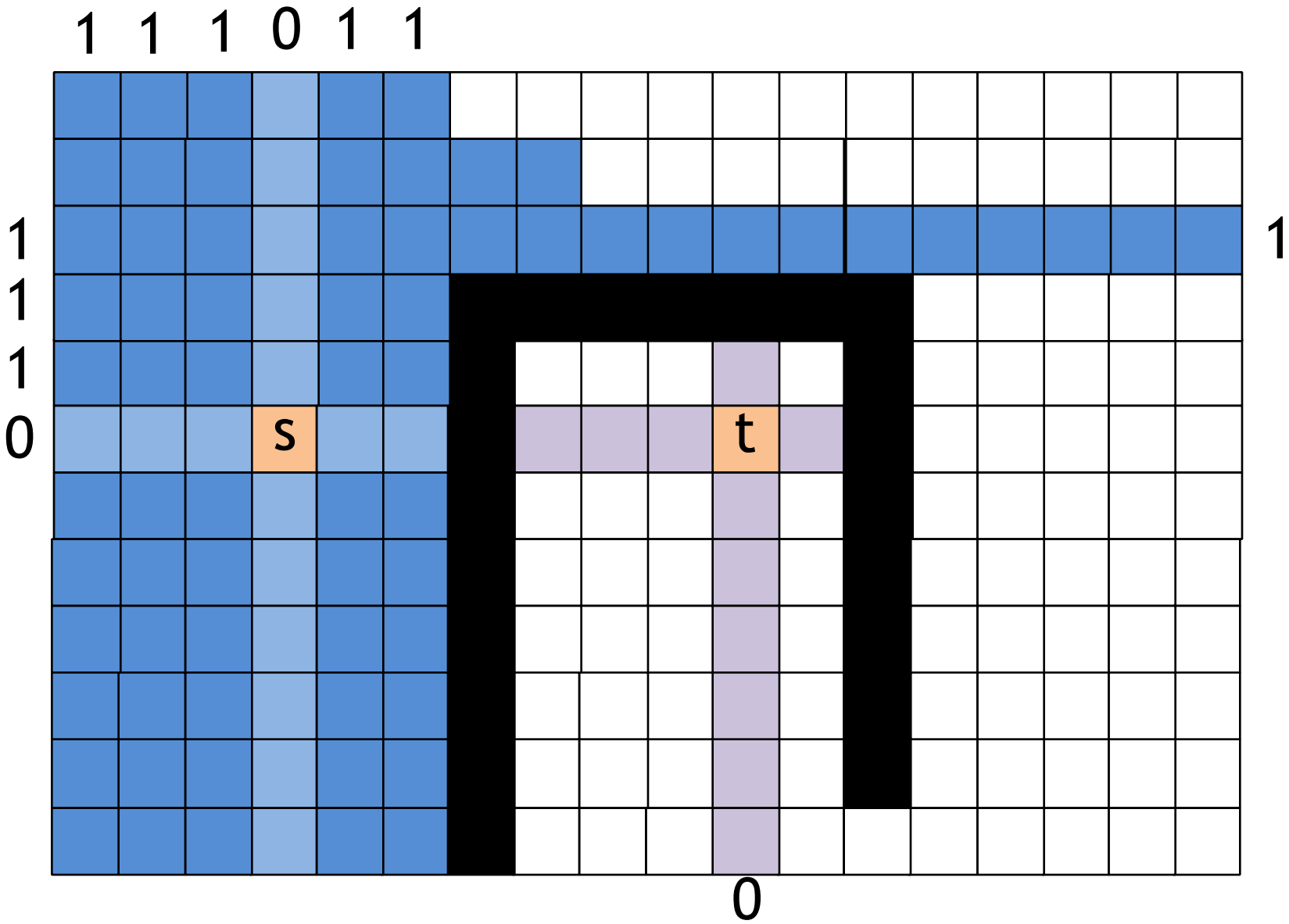
Source Line Probe (Level 1)



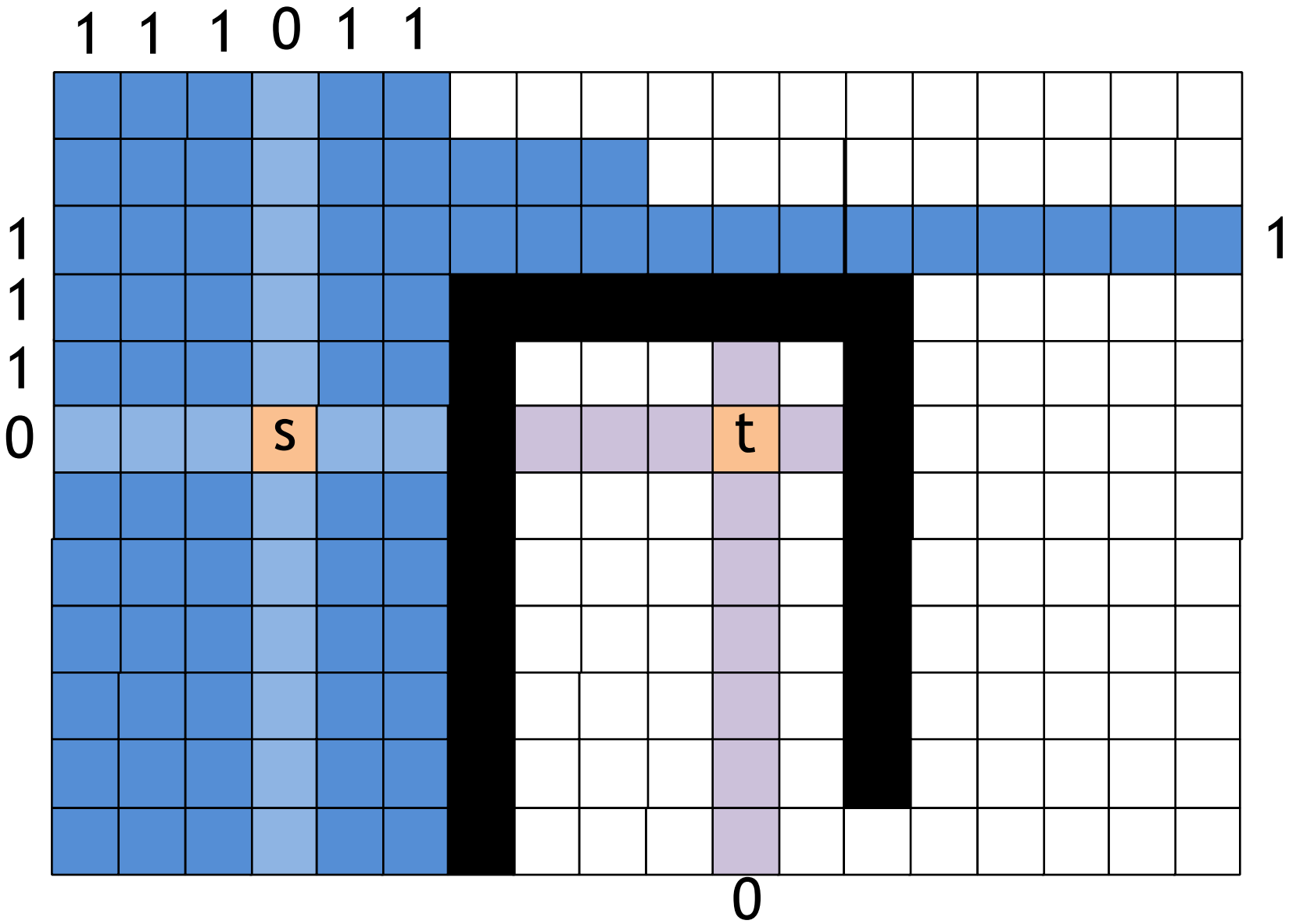
Source Line Probe (Level 1)



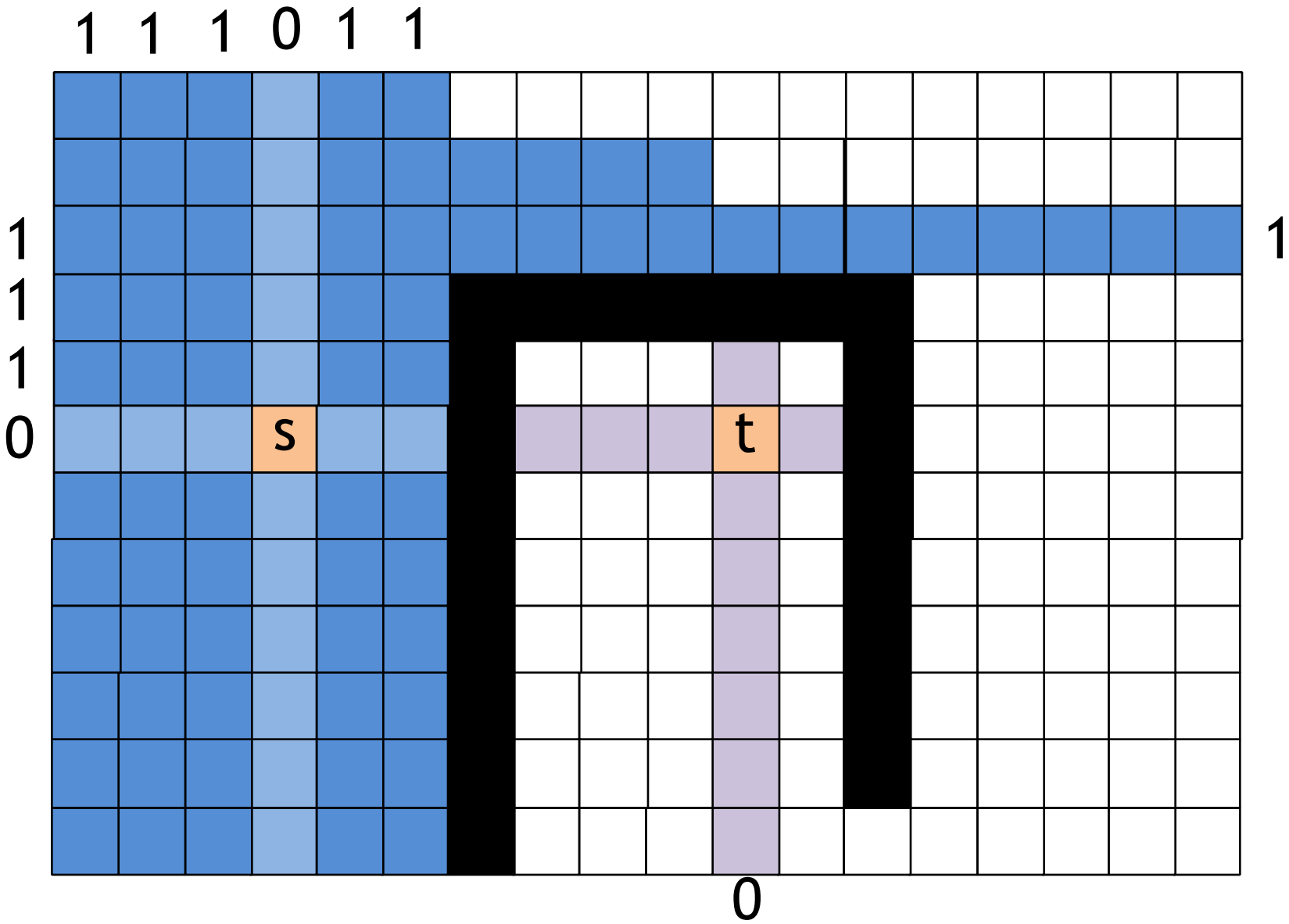
Source Line Probe (Level 1)



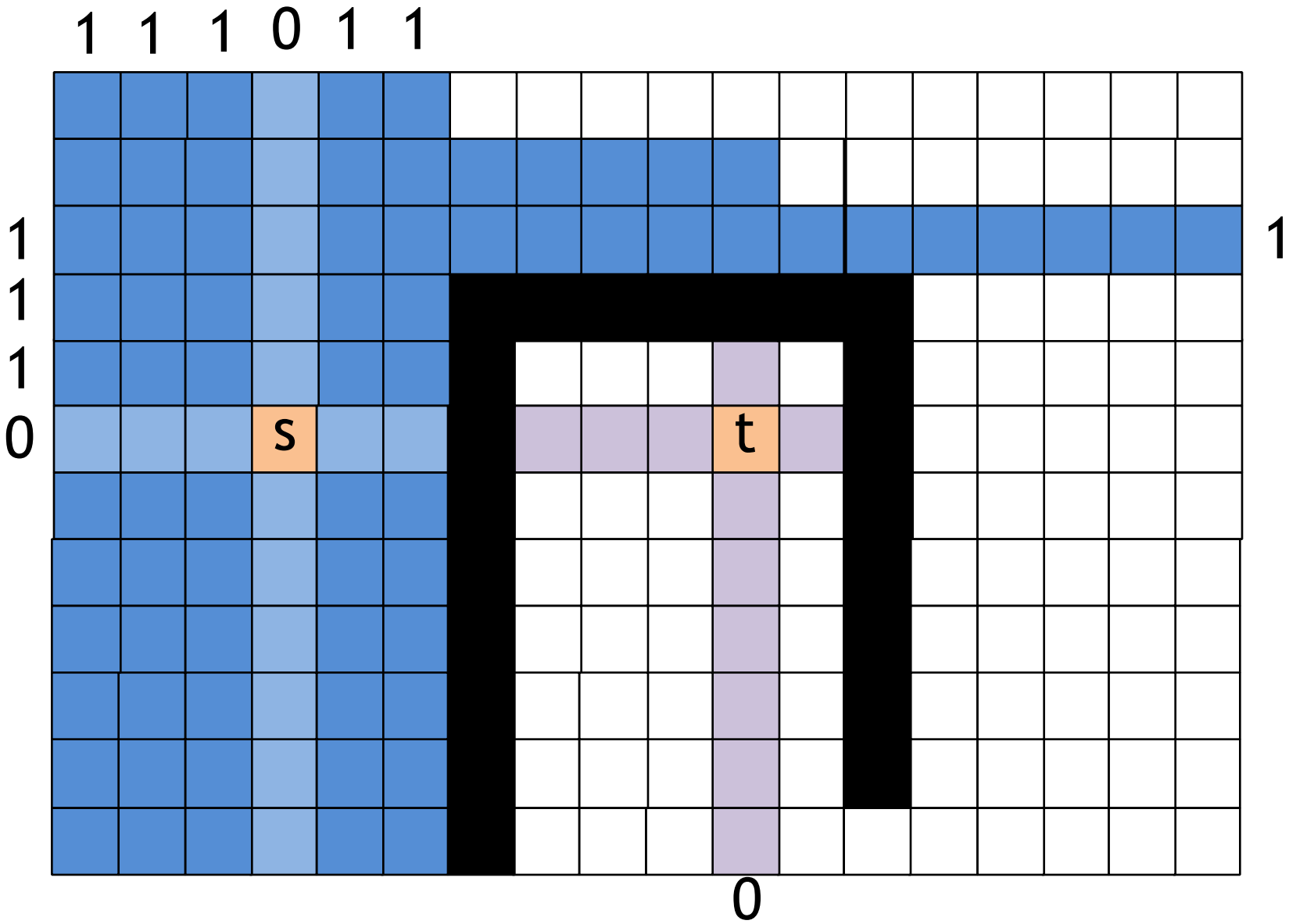
Source Line Probe (Level 1)



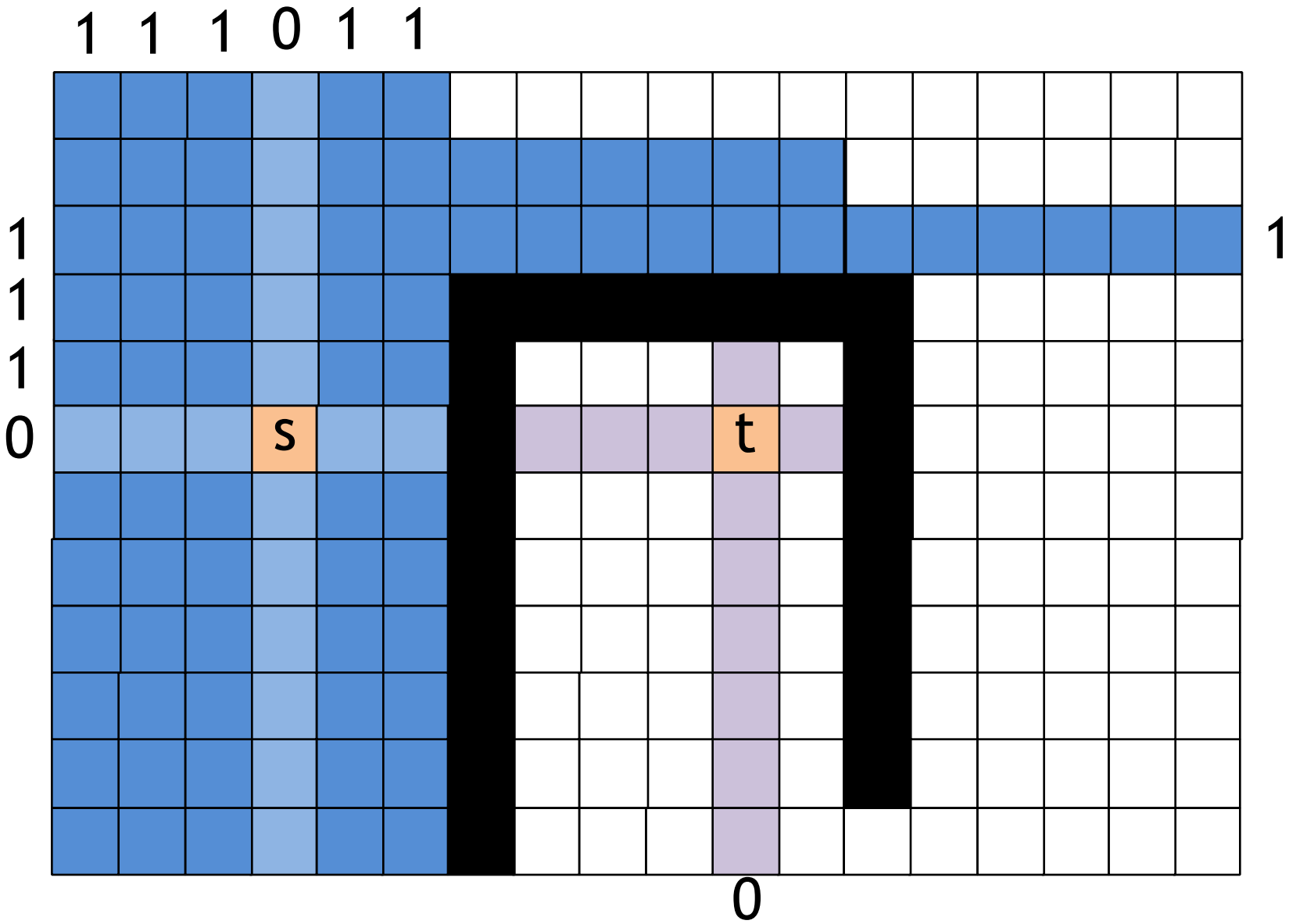
Source Line Probe (Level 1)



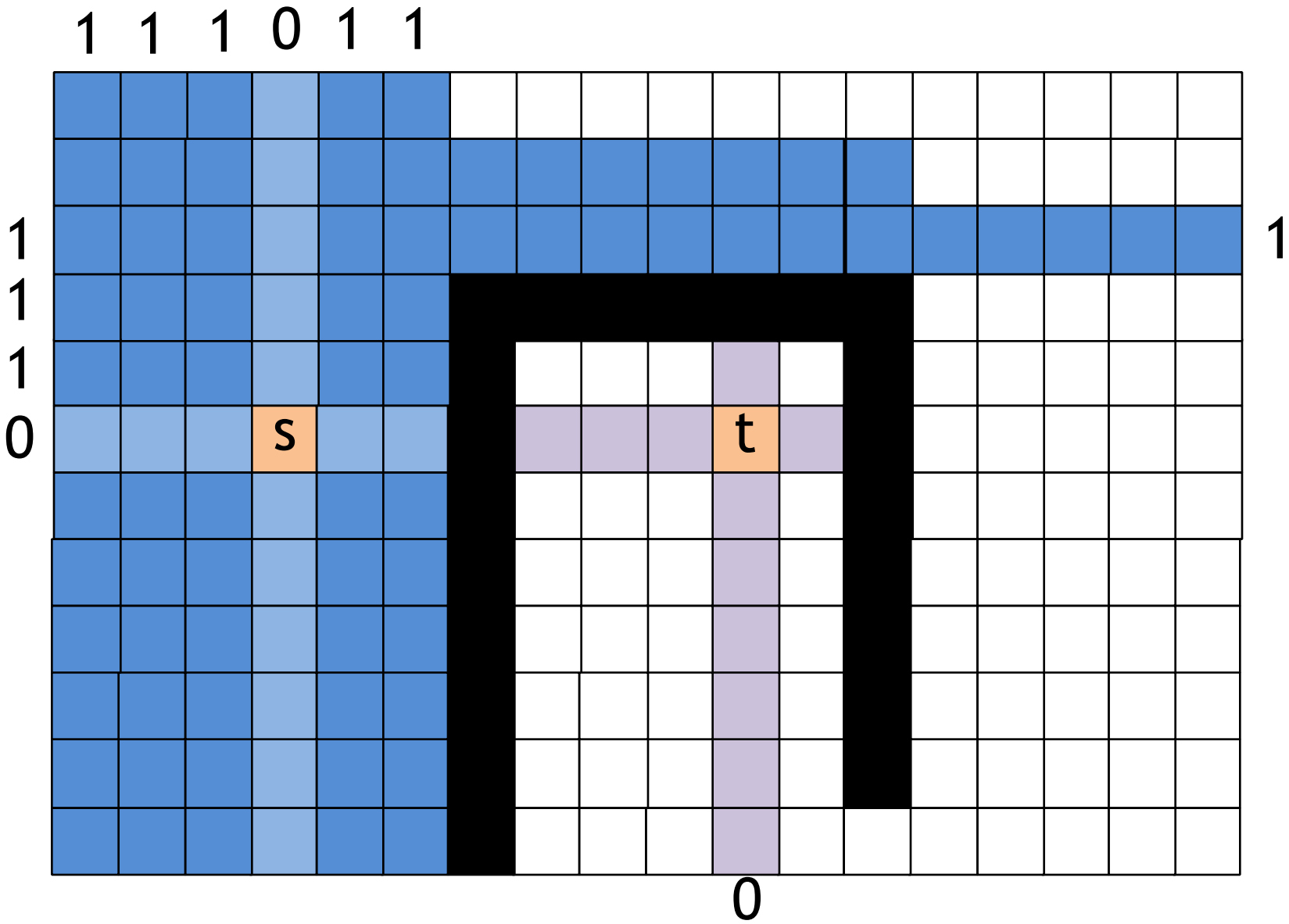
Source Line Probe (Level 1)



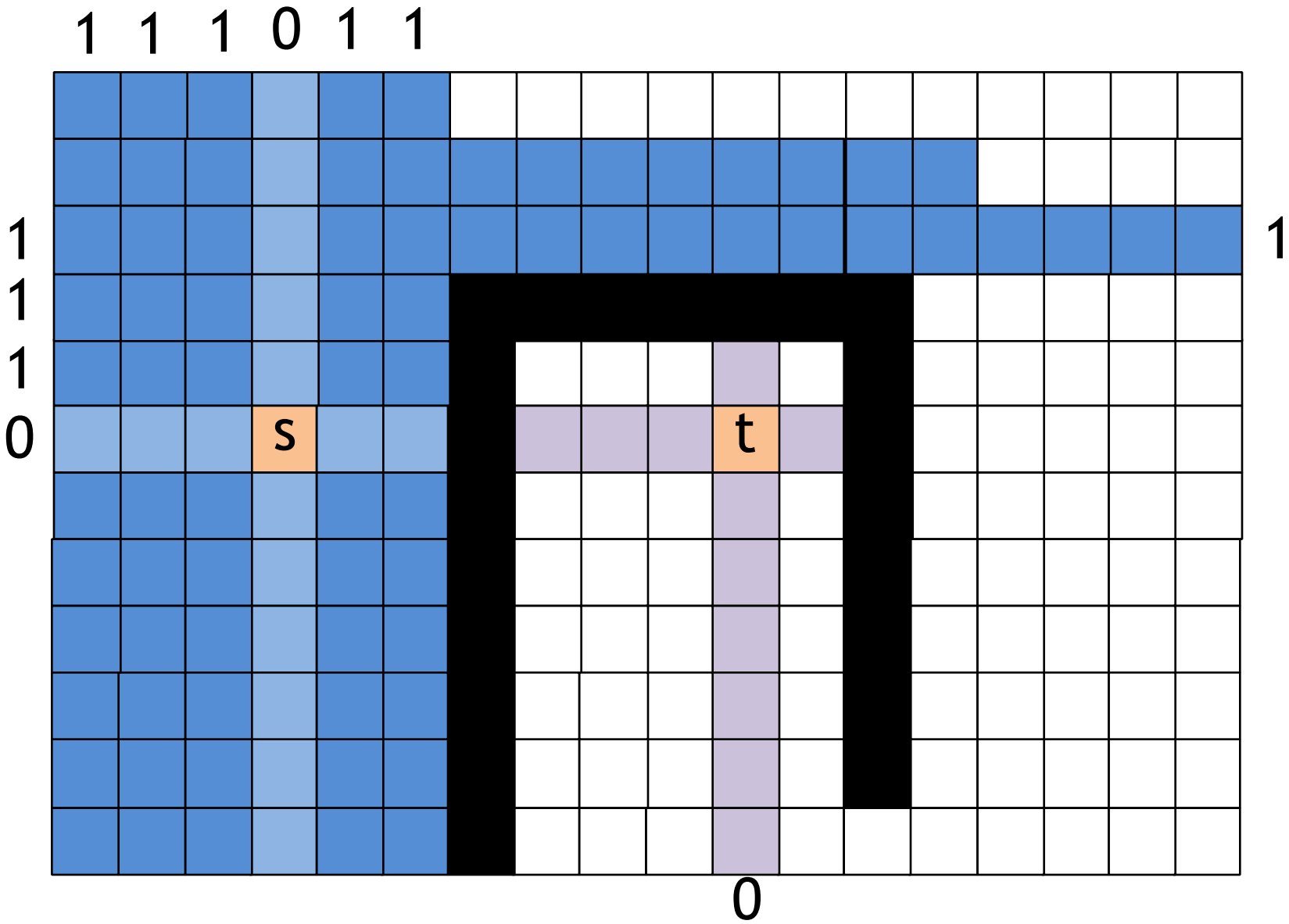
Source Line Probe (Level 1)



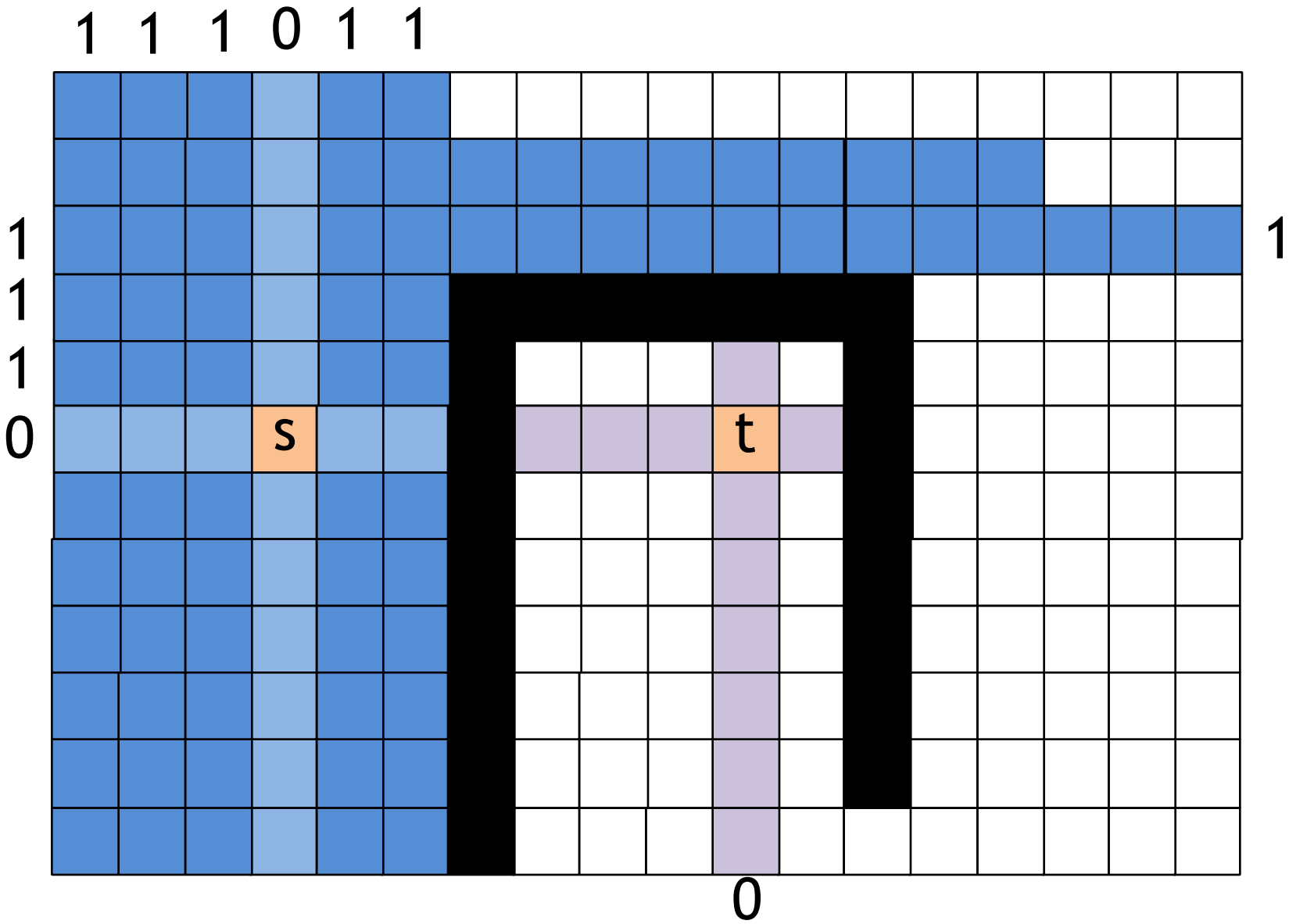
Source Line Probe (Level 1)



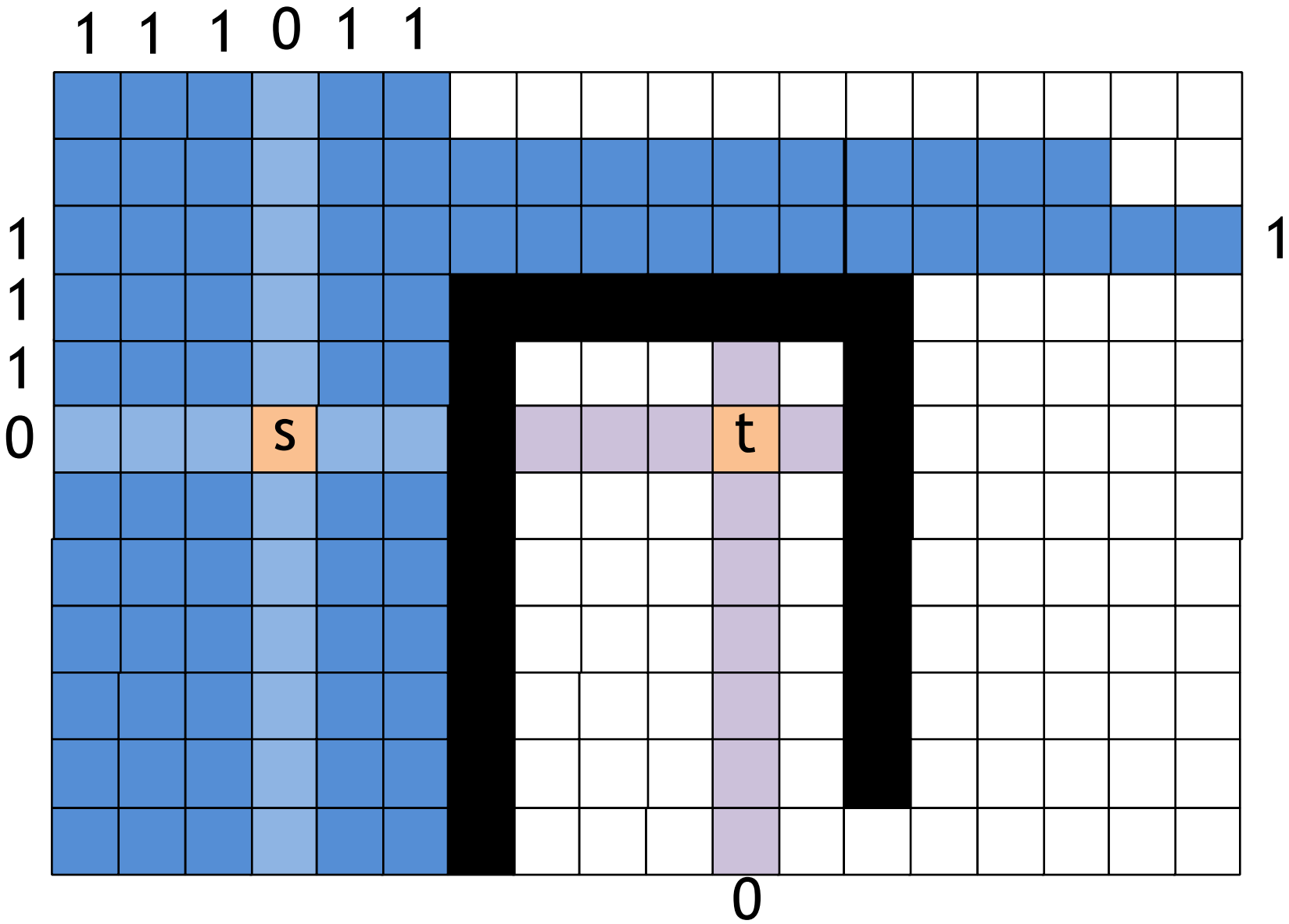
Source Line Probe (Level 1)



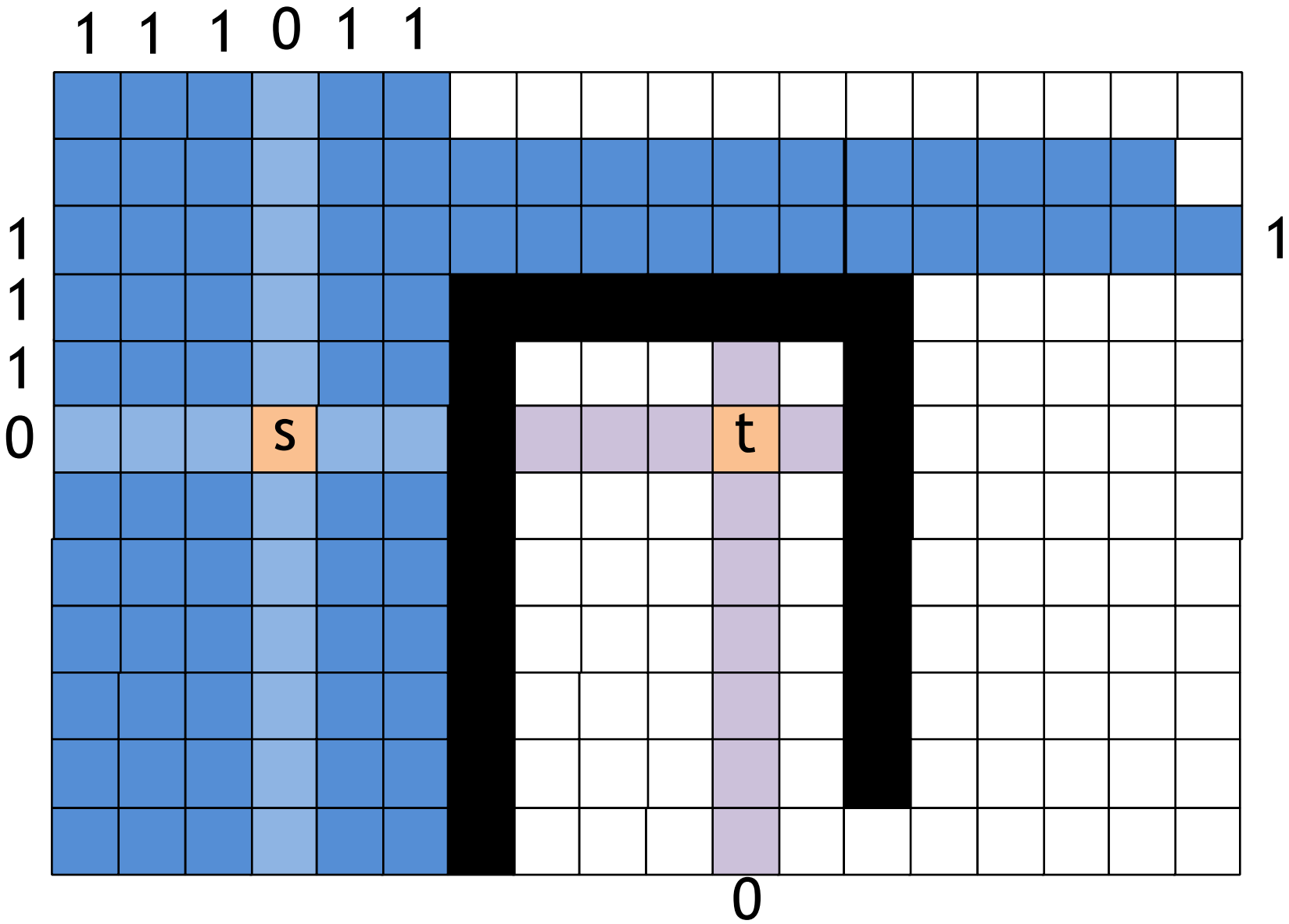
Source Line Probe (Level 1)



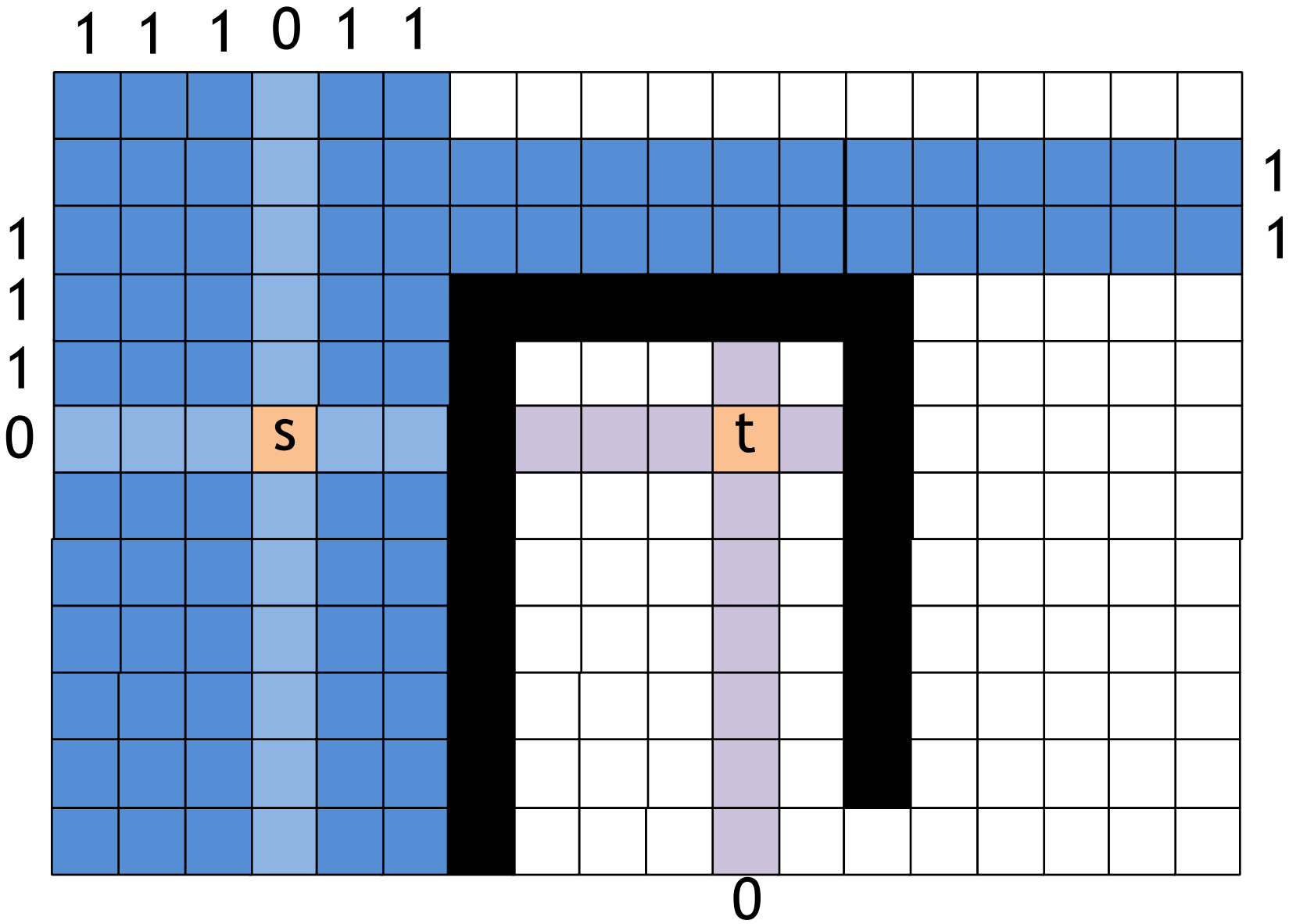
Source Line Probe (Level 1)



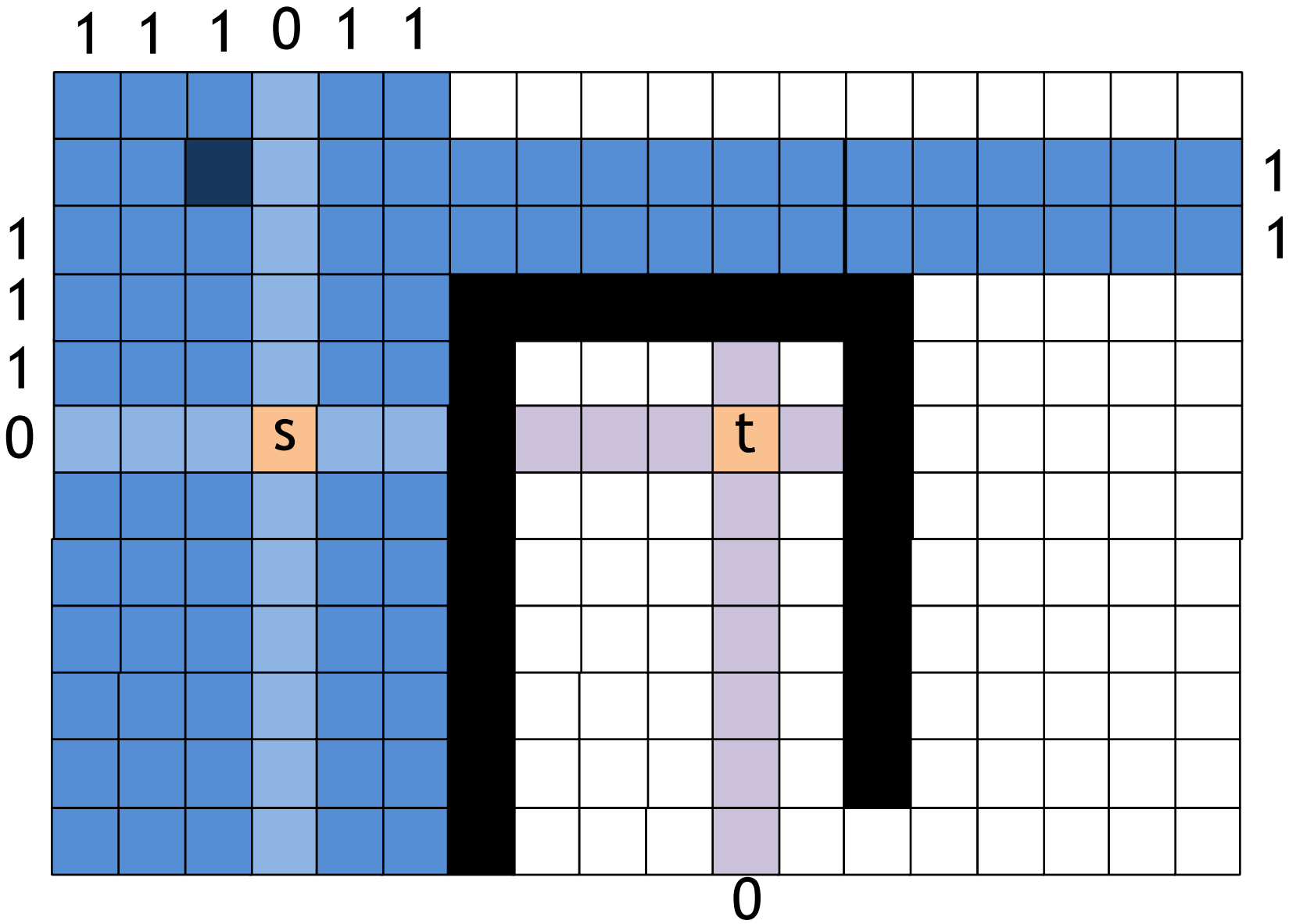
Source Line Probe (Level 1)



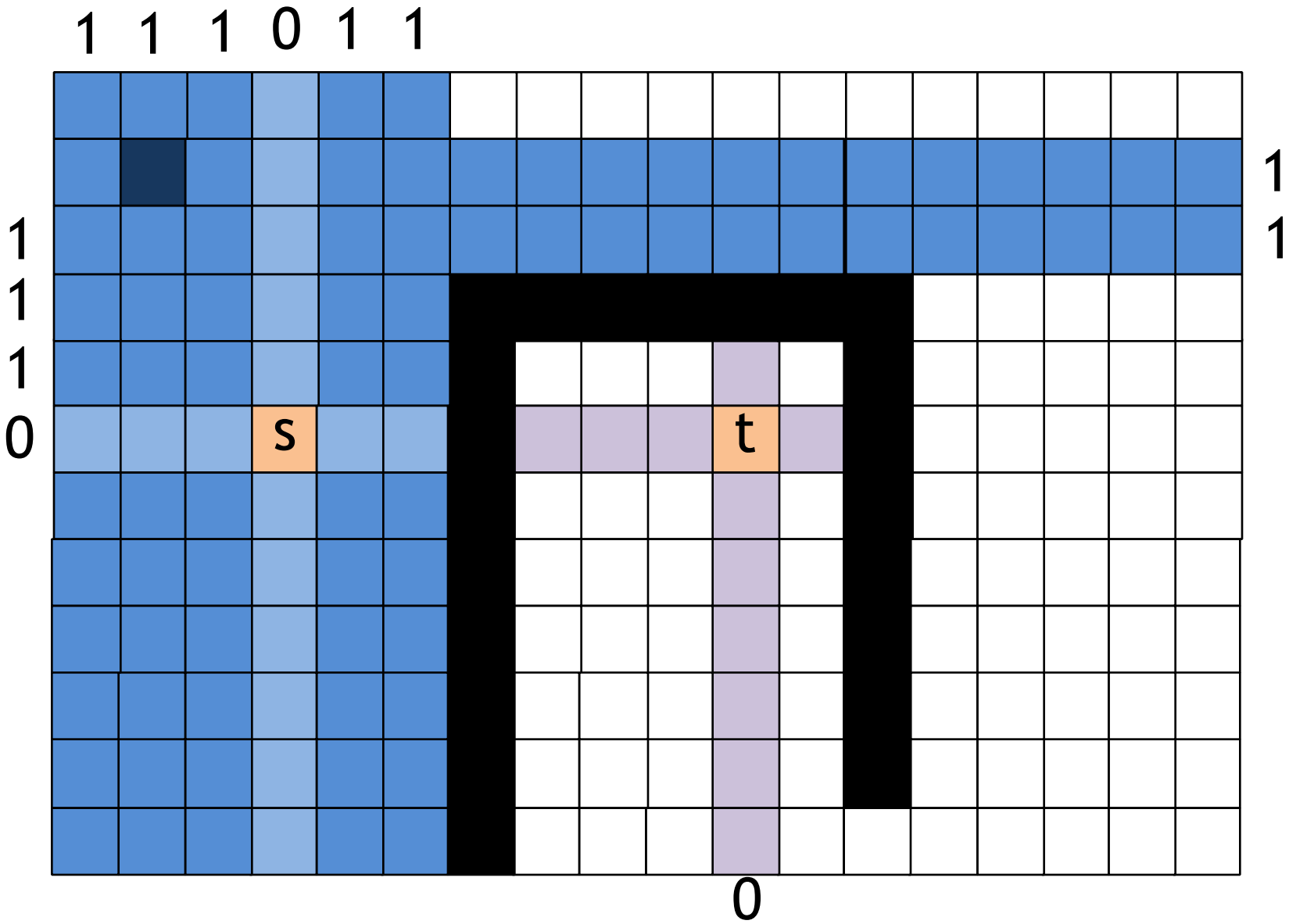
Source Line Probe (Level 1)



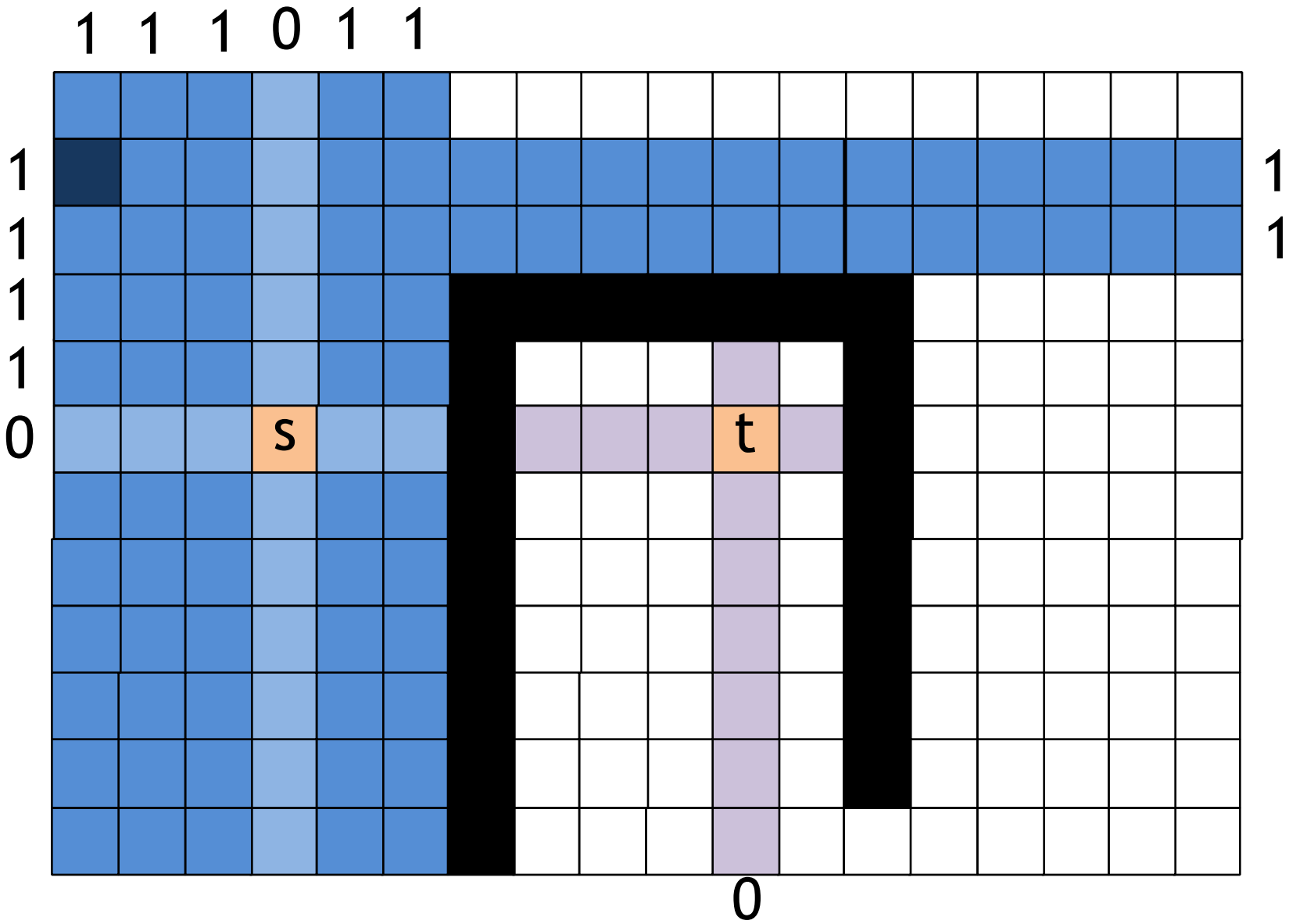
Source Line Probe (Level 1)



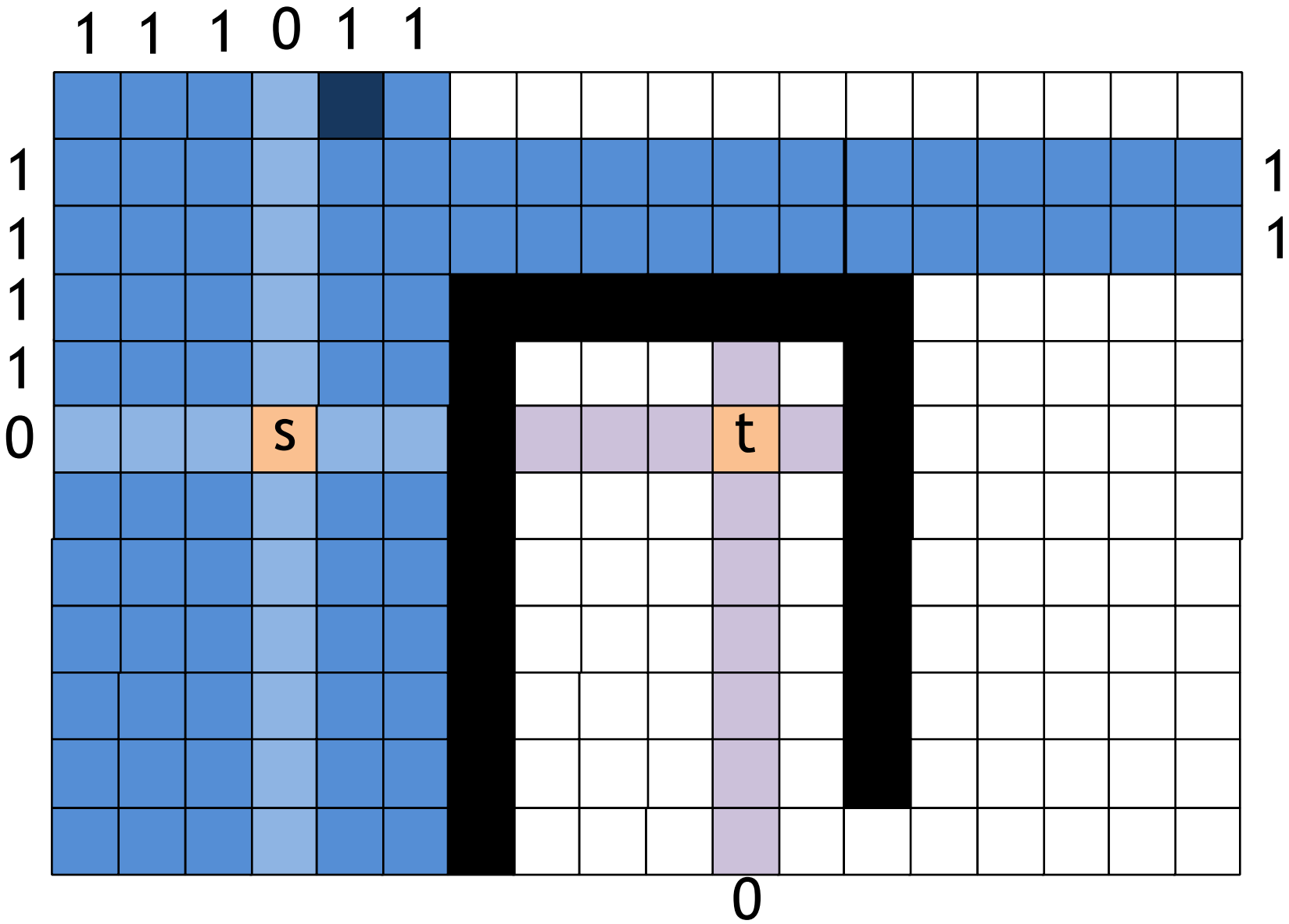
Source Line Probe (Level 1)



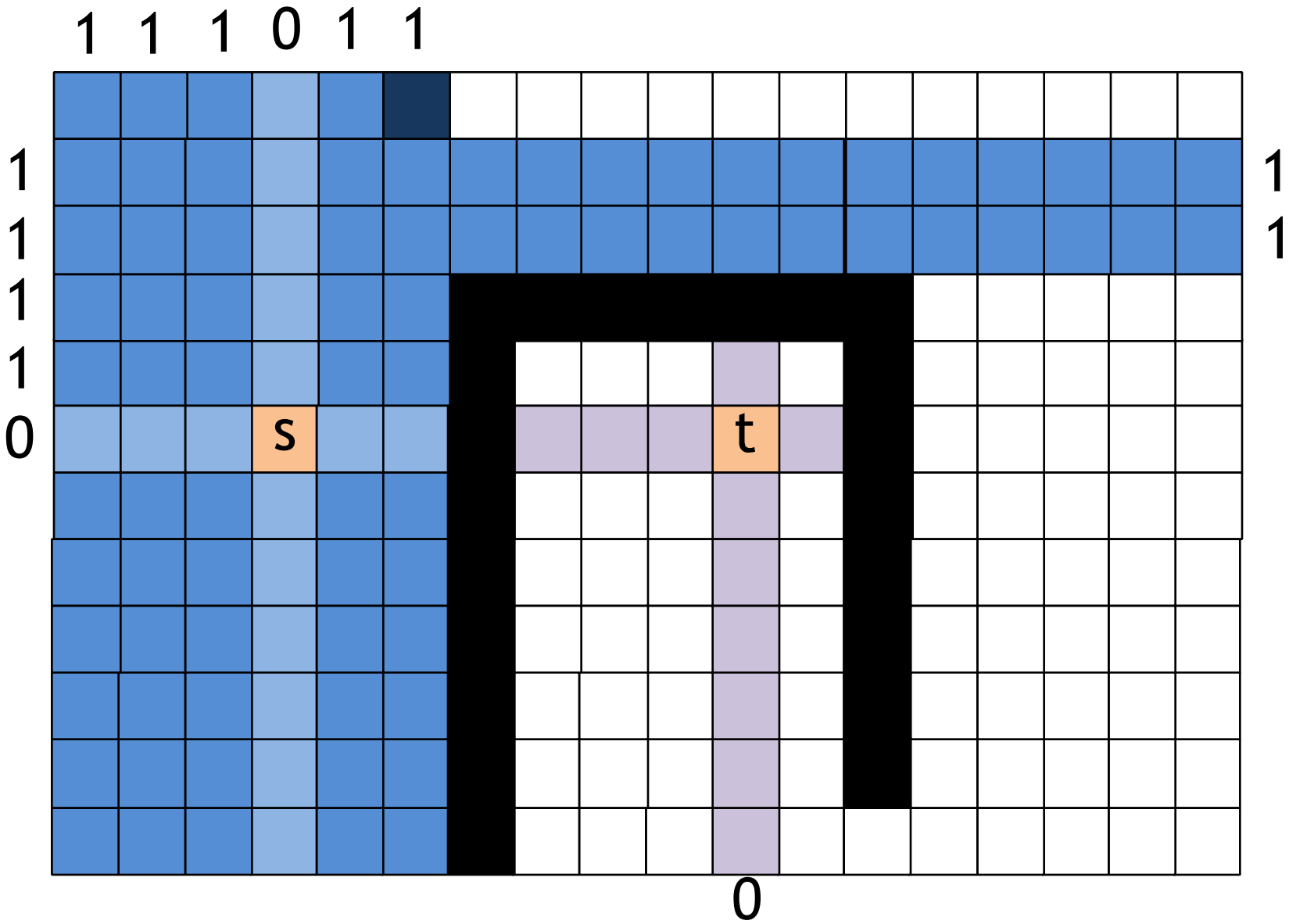
Source Line Probe (Level 1)



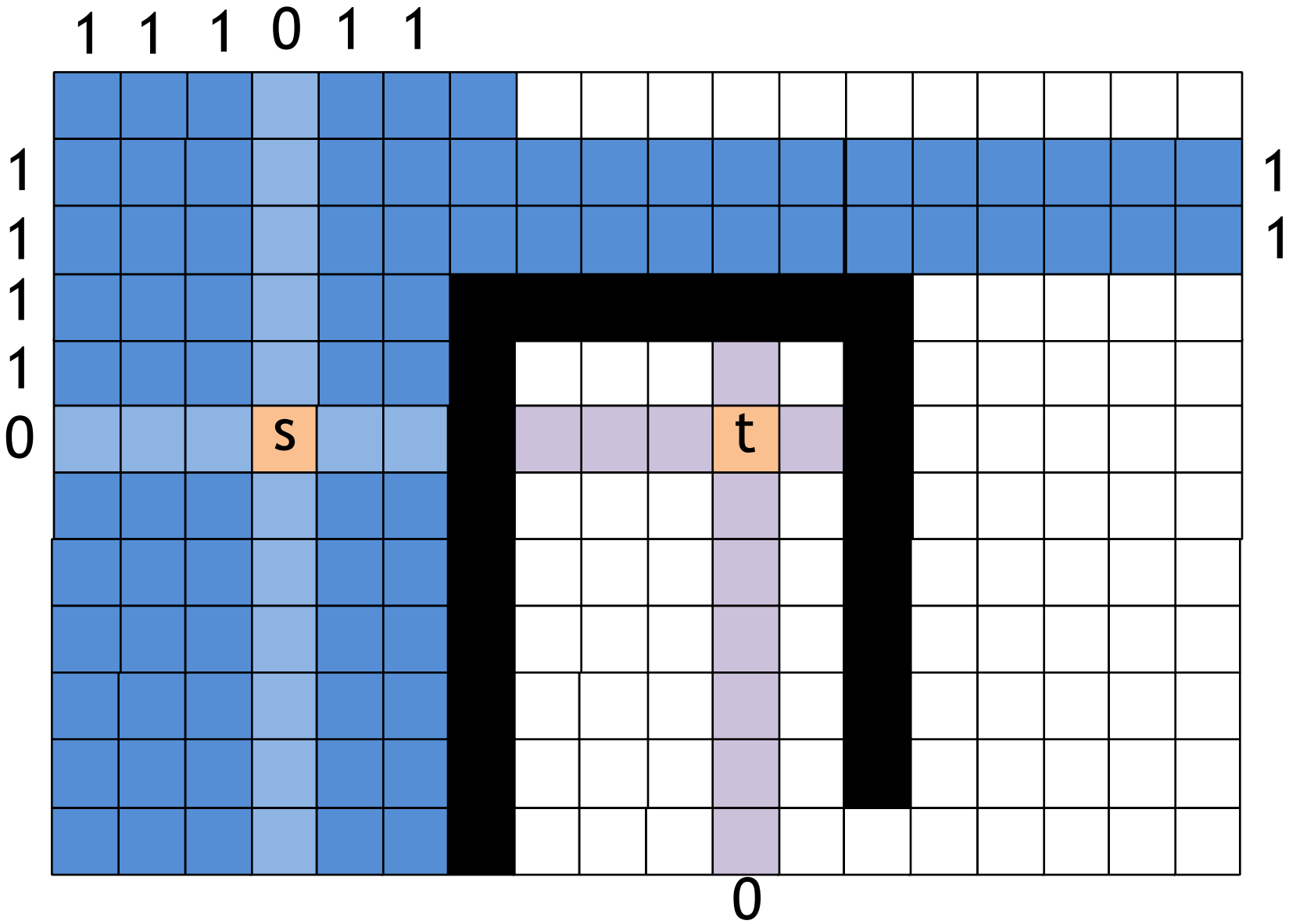
Source Line Probe (Level 1)



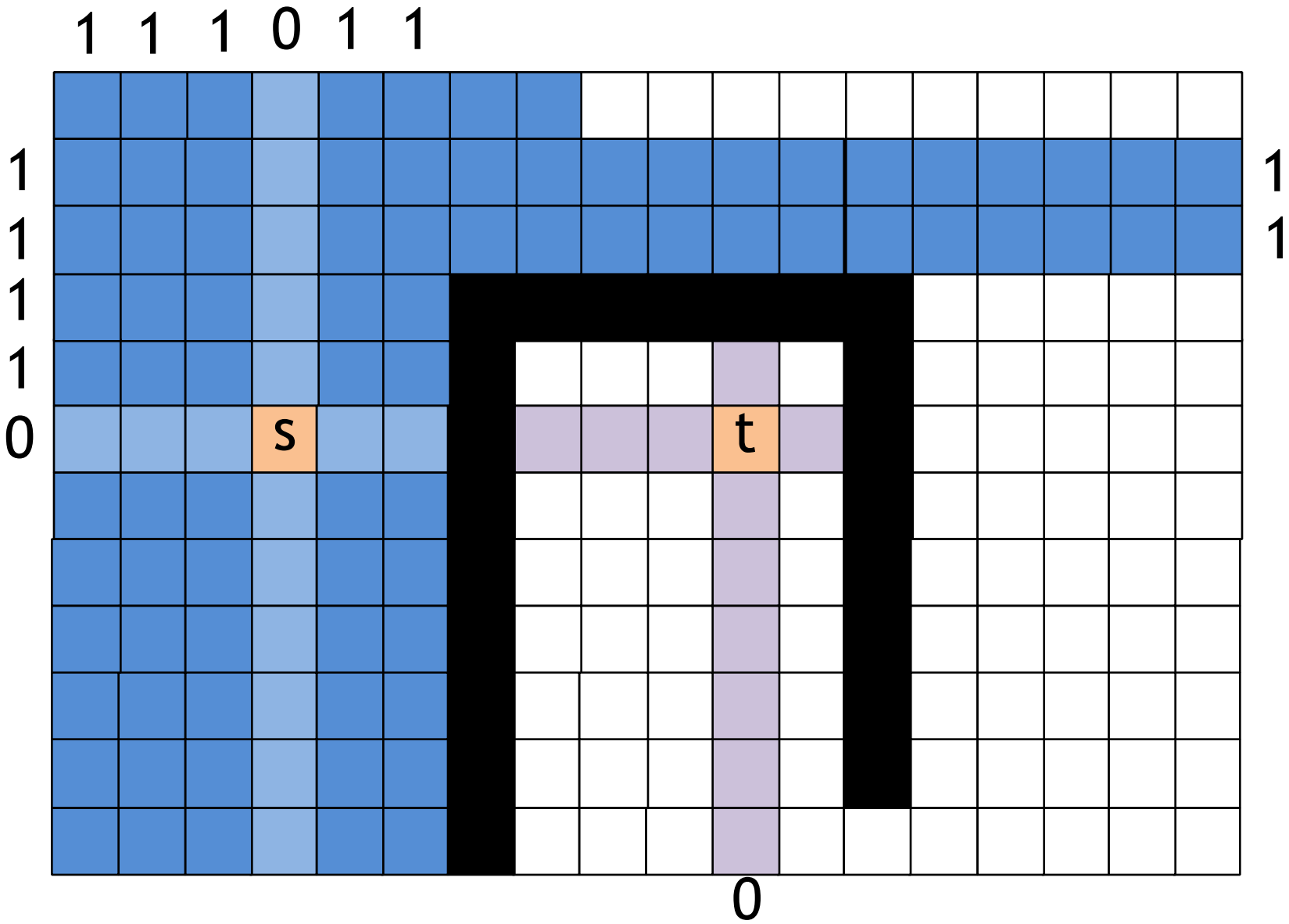
Source Line Probe (Level 1)



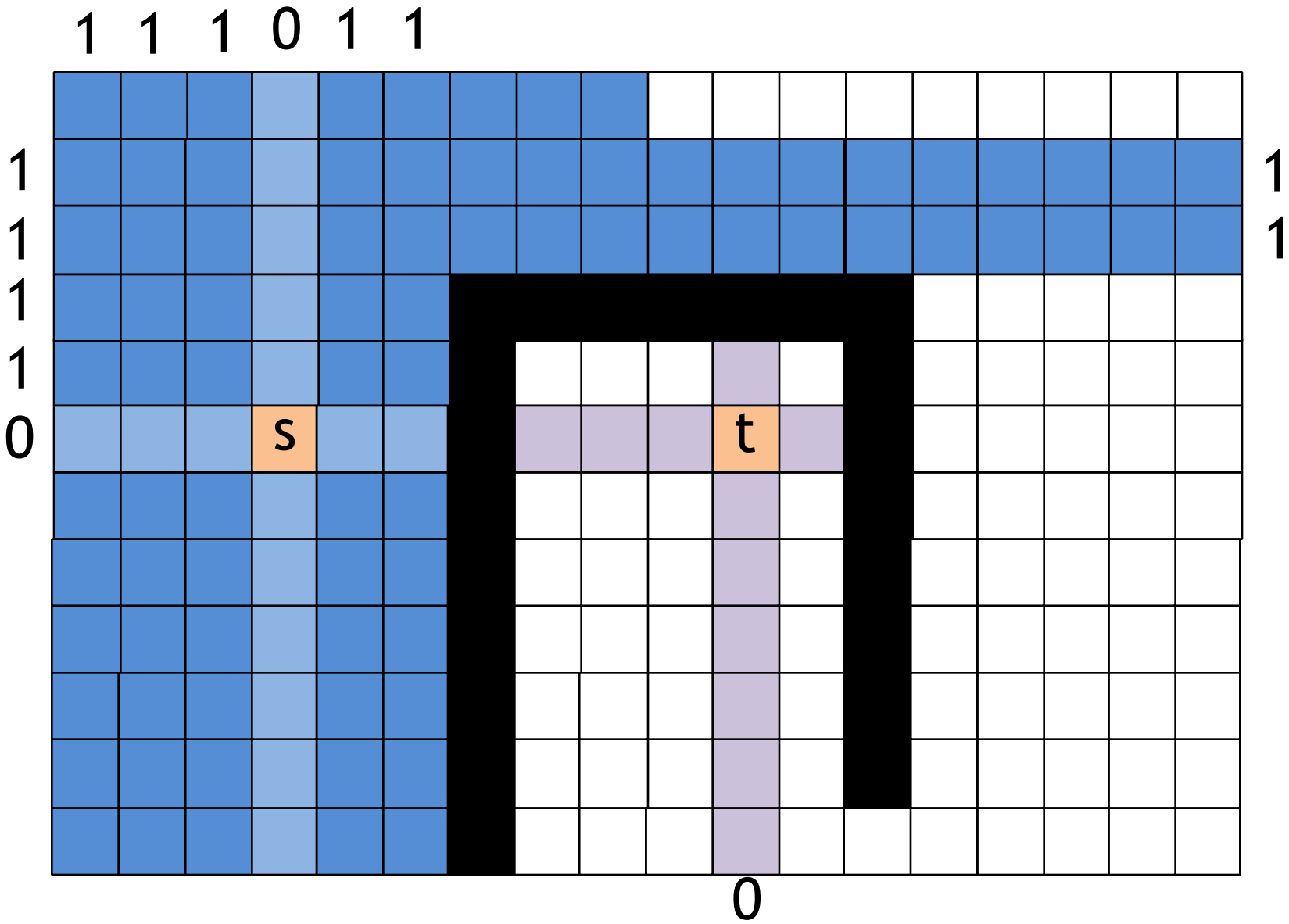
Source Line Probe (Level 1)



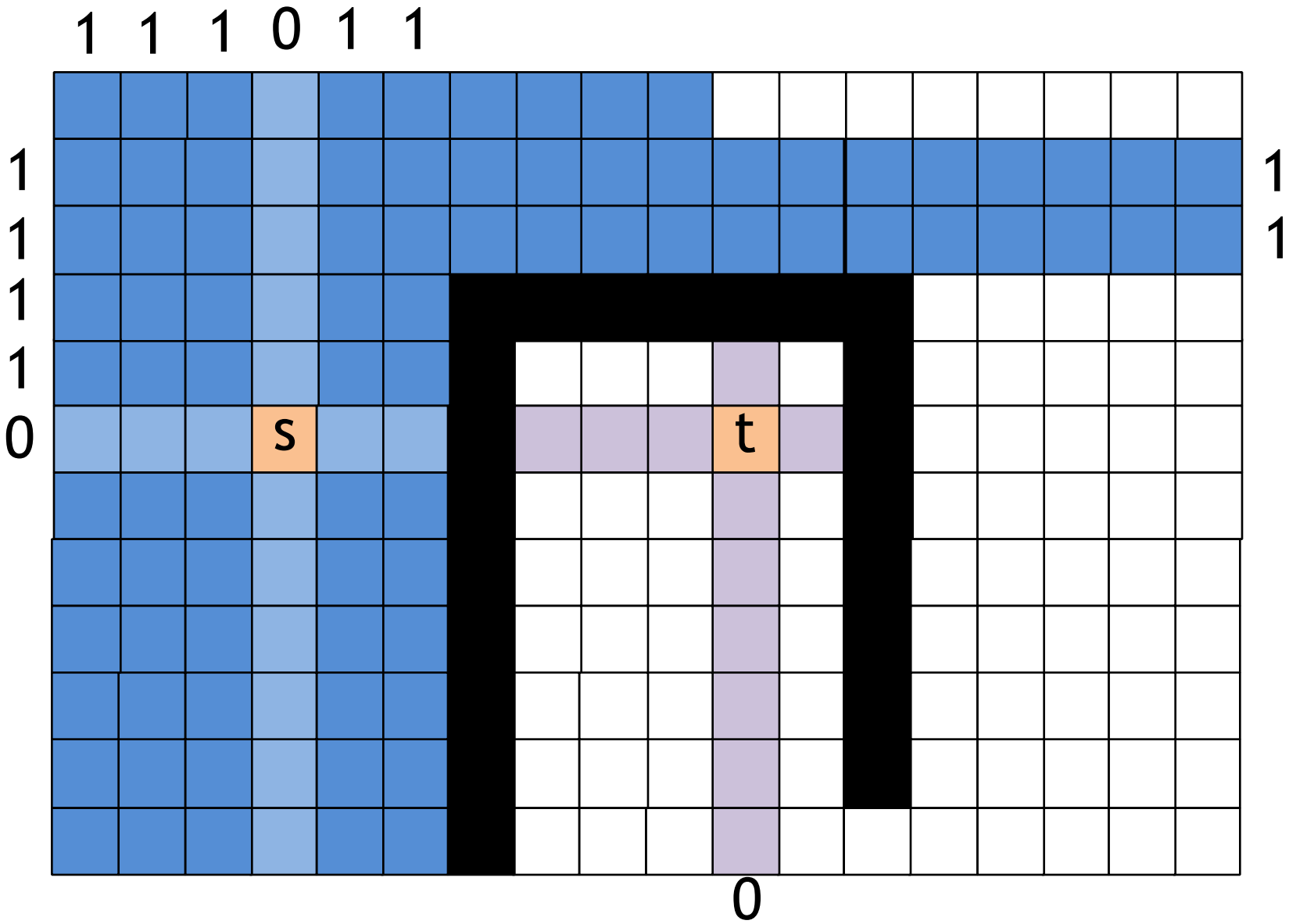
Source Line Probe (Level 1)



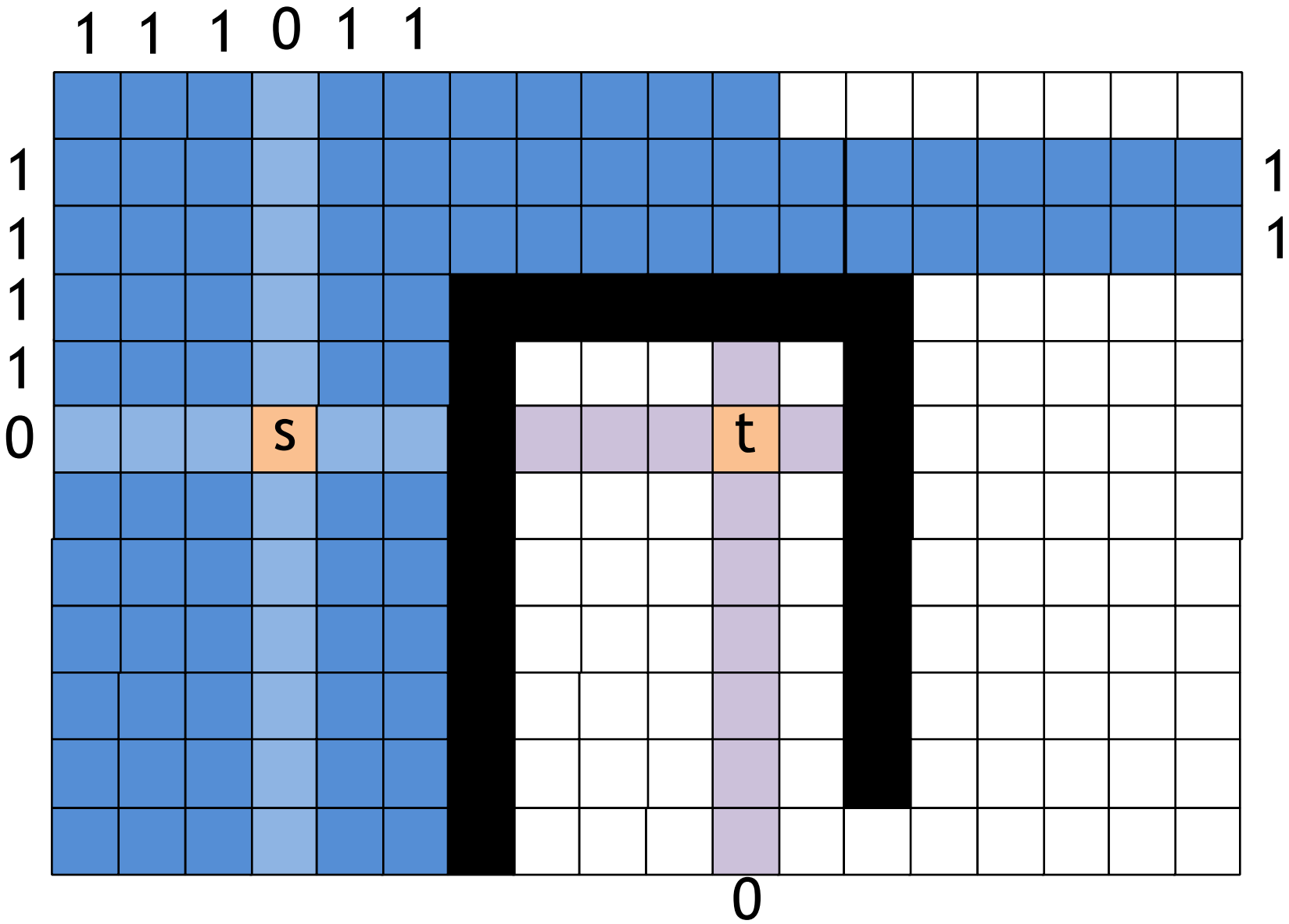
Source Line Probe (Level 1)



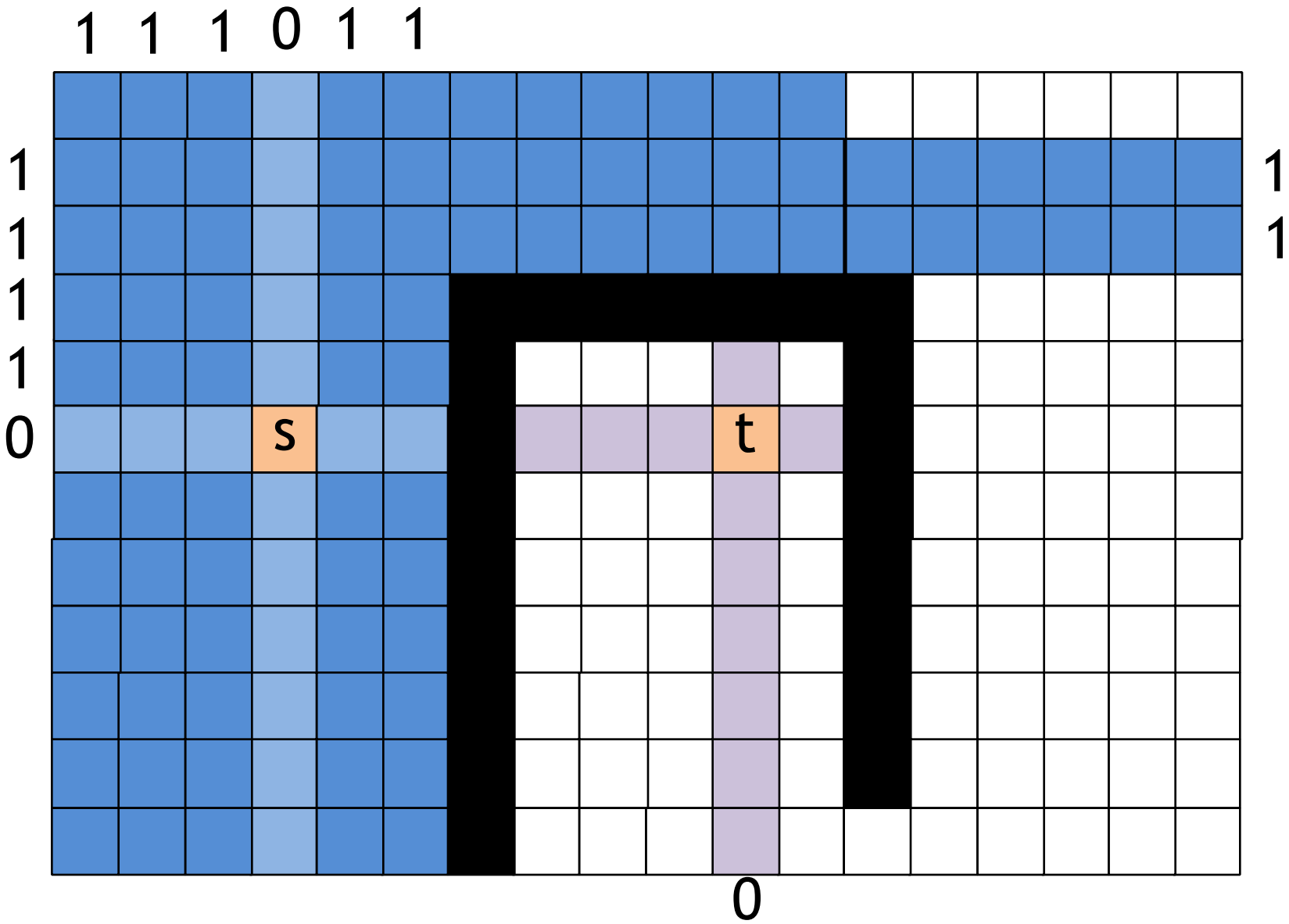
Source Line Probe (Level 1)



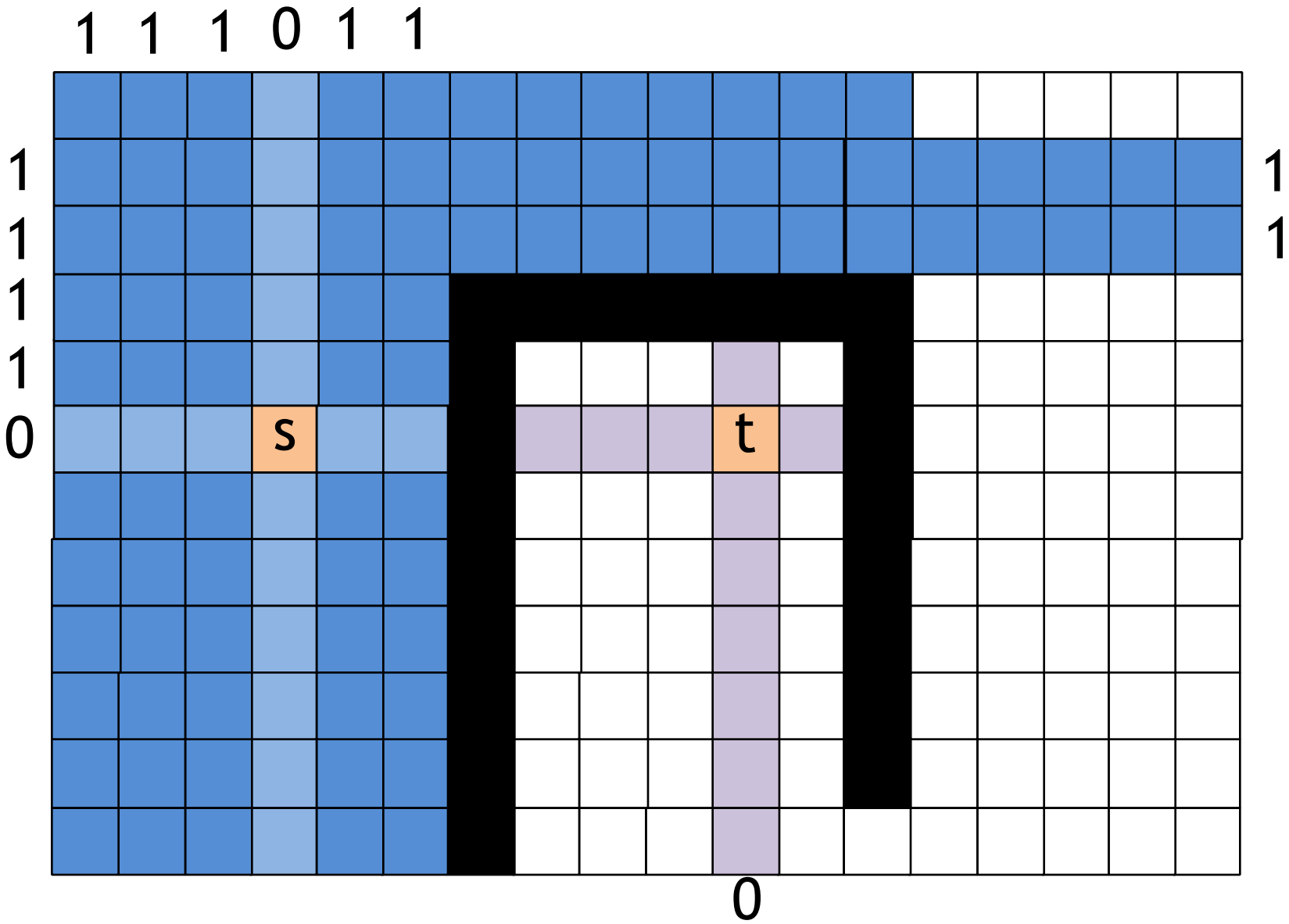
Source Line Probe (Level 1)



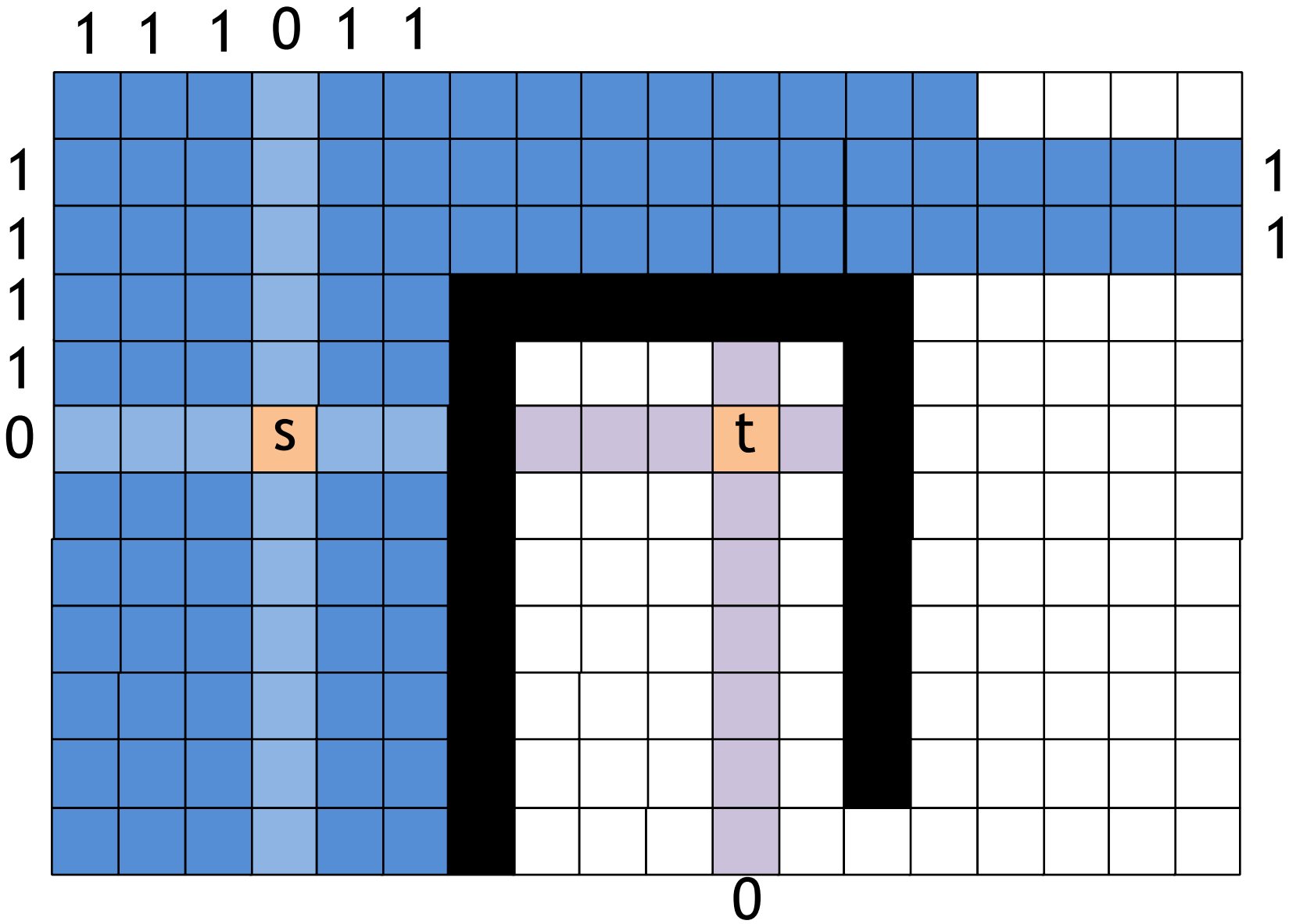
Source Line Probe (Level 1)



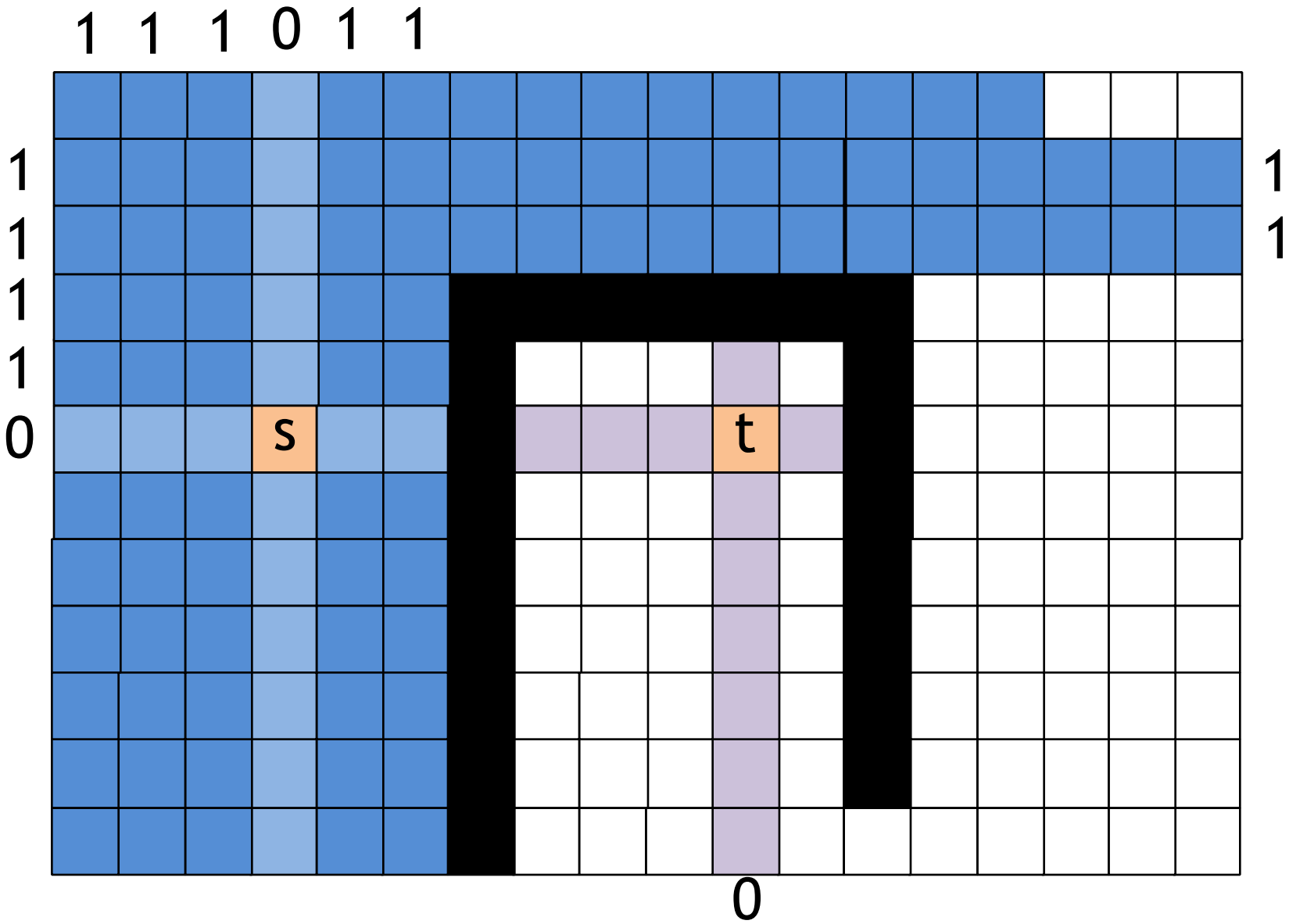
Source Line Probe (Level 1)



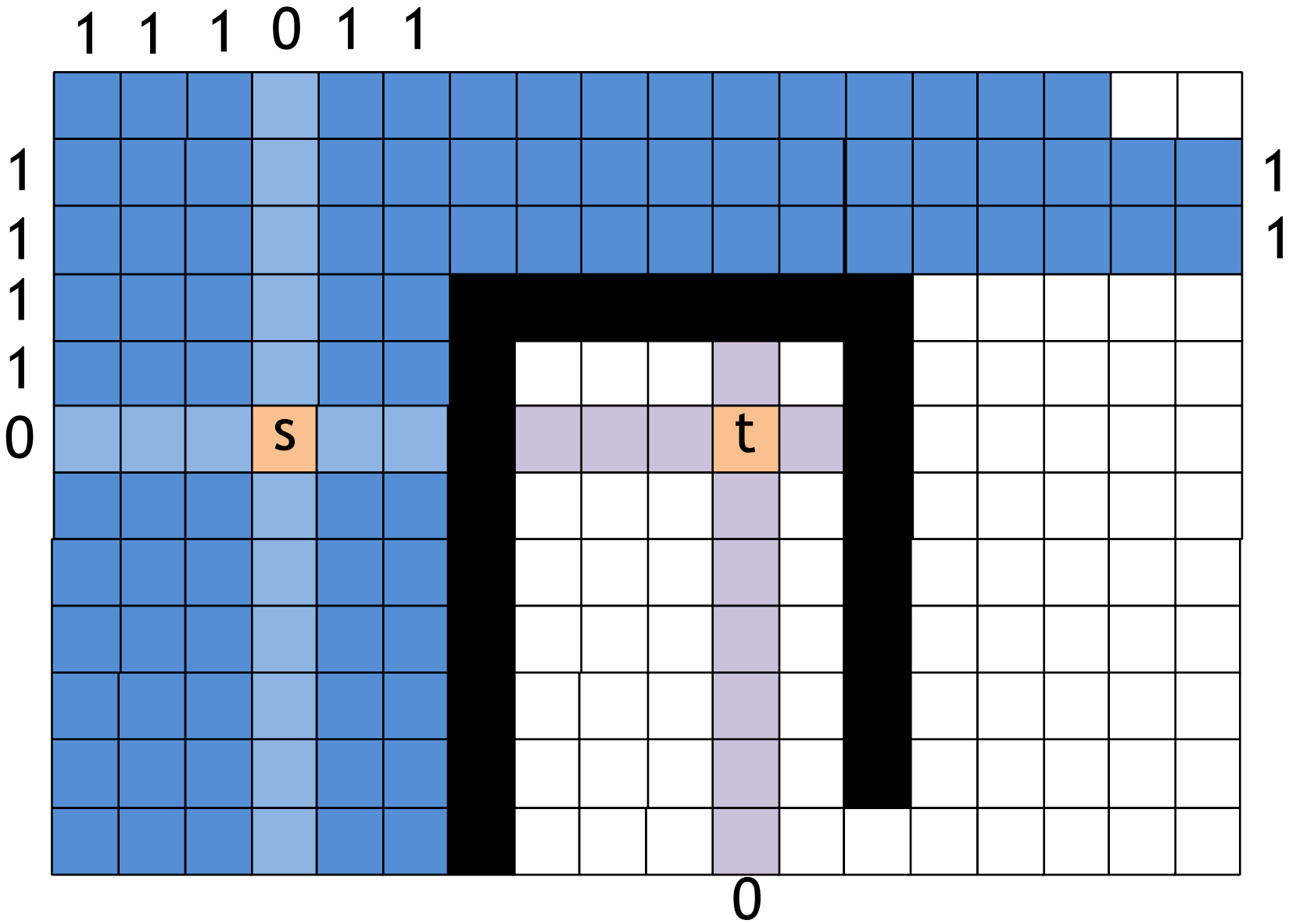
Source Line Probe (Level 1)



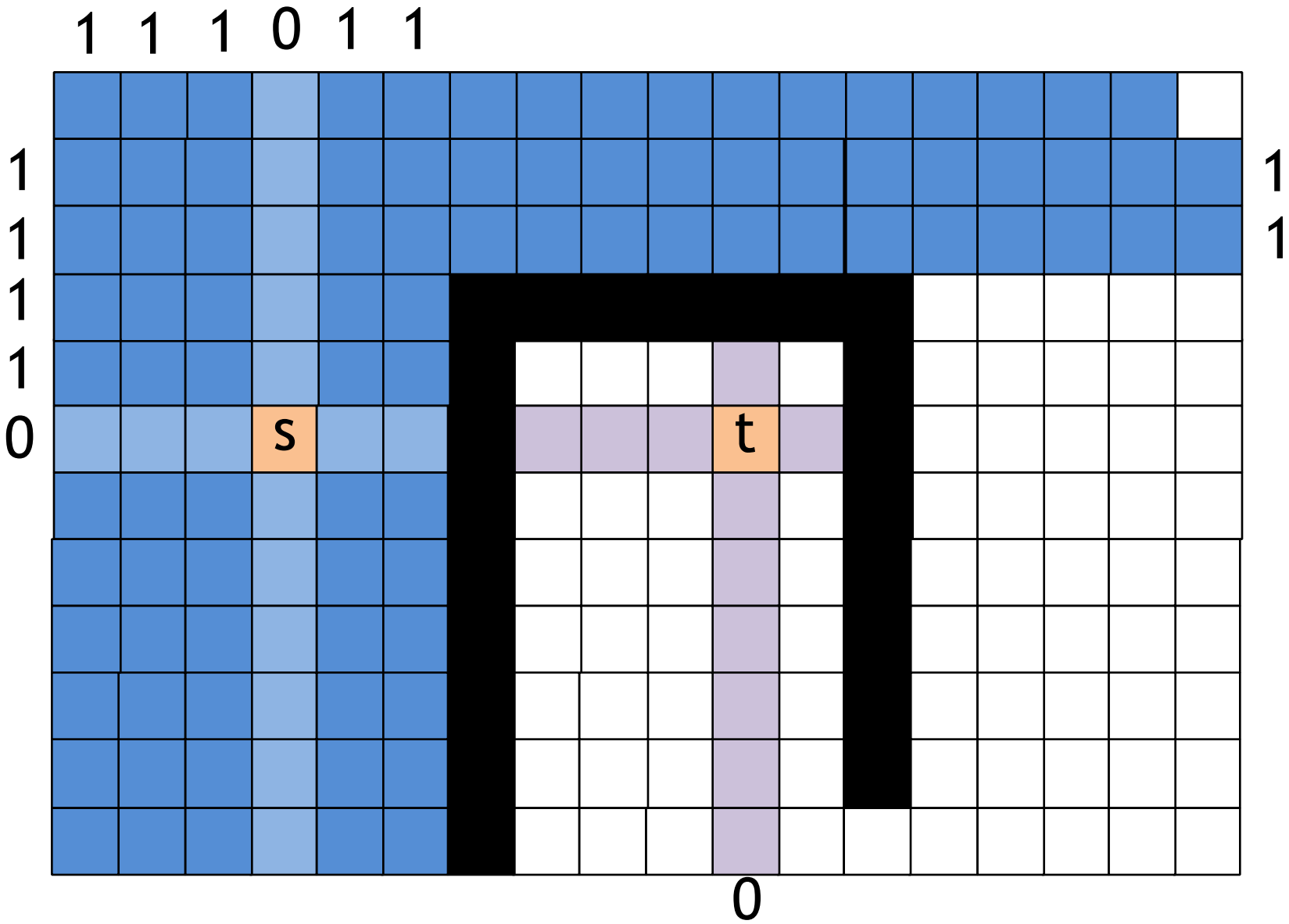
Source Line Probe (Level 1)



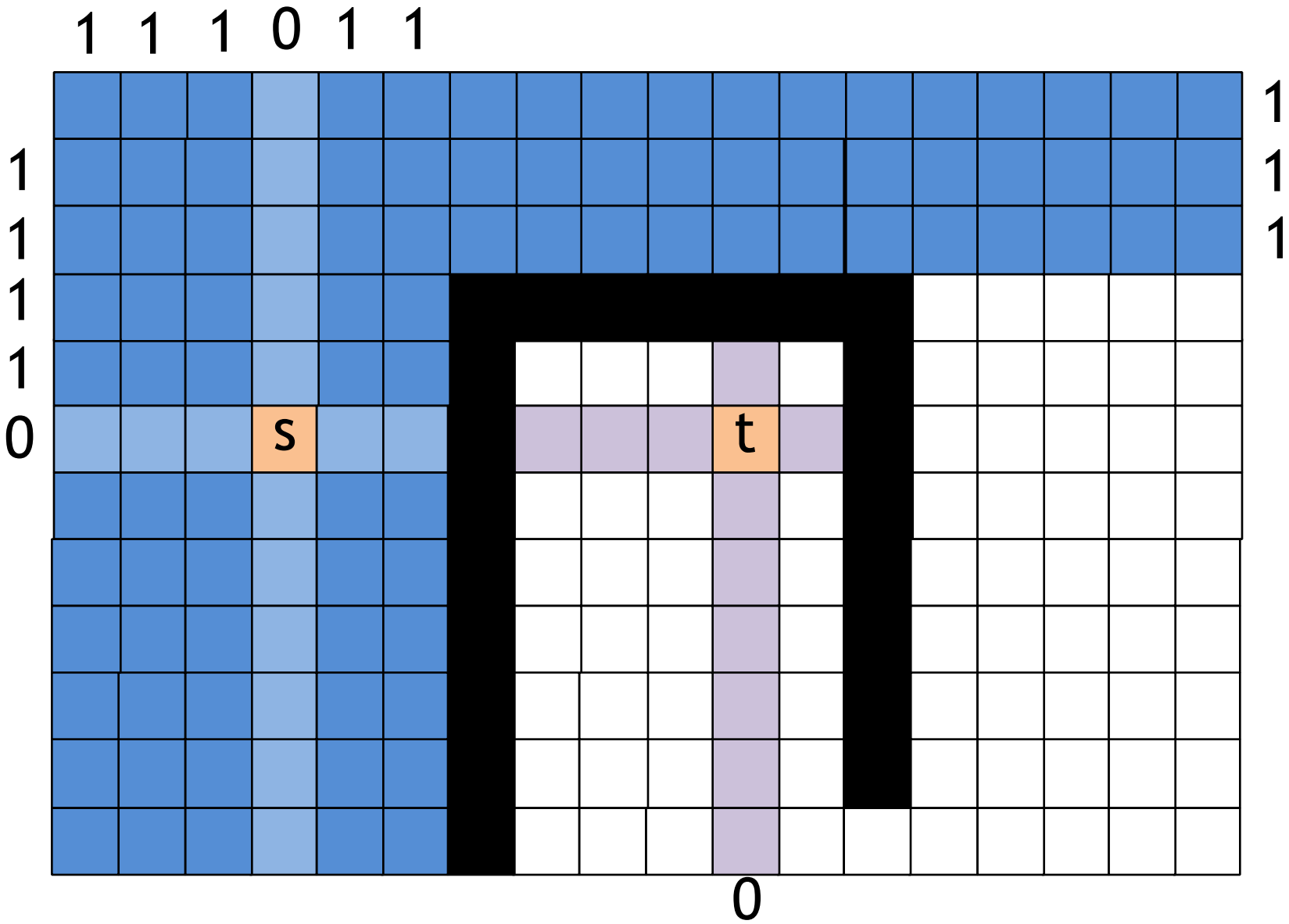
Source Line Probe (Level 1)



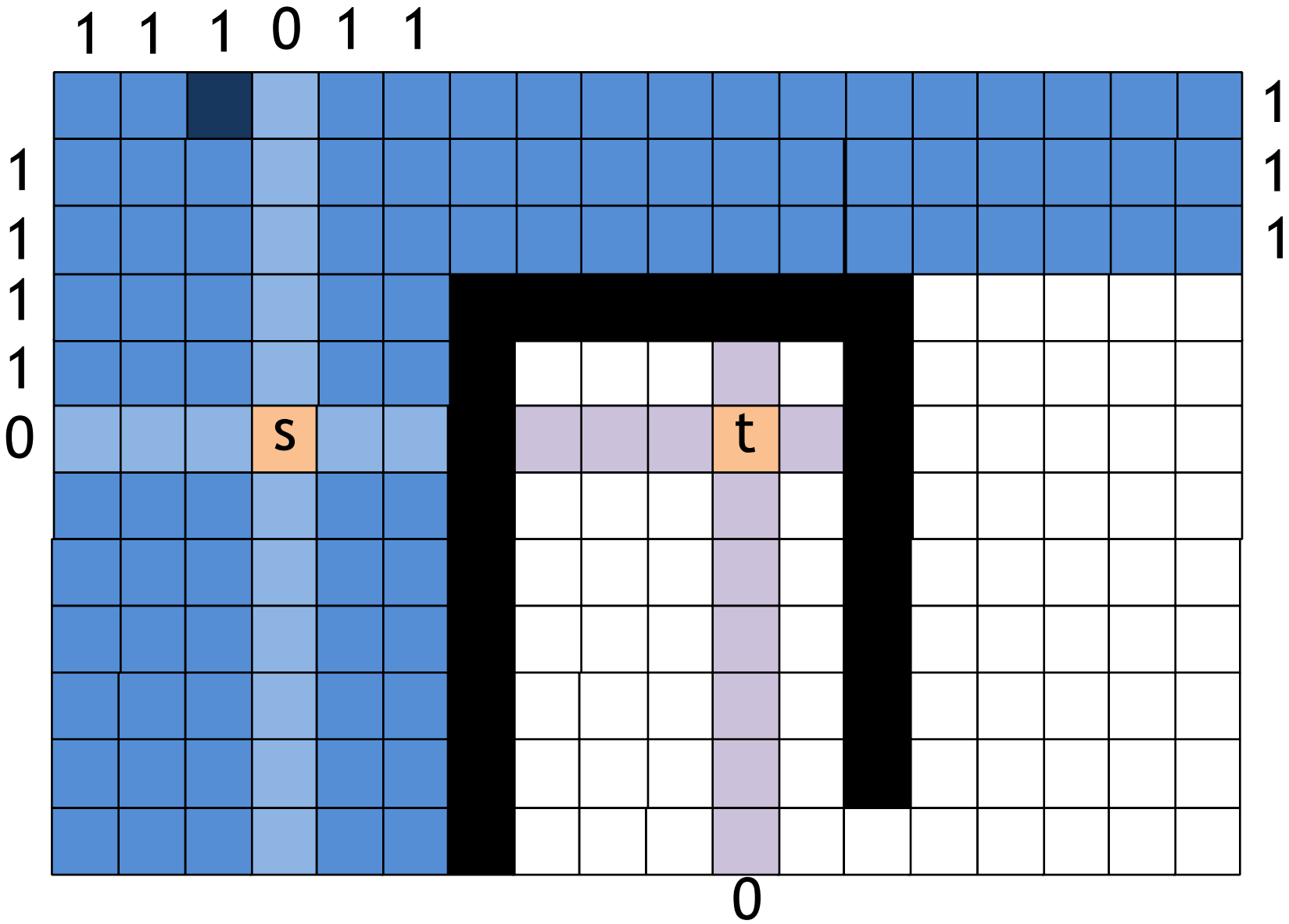
Source Line Probe (Level 1)



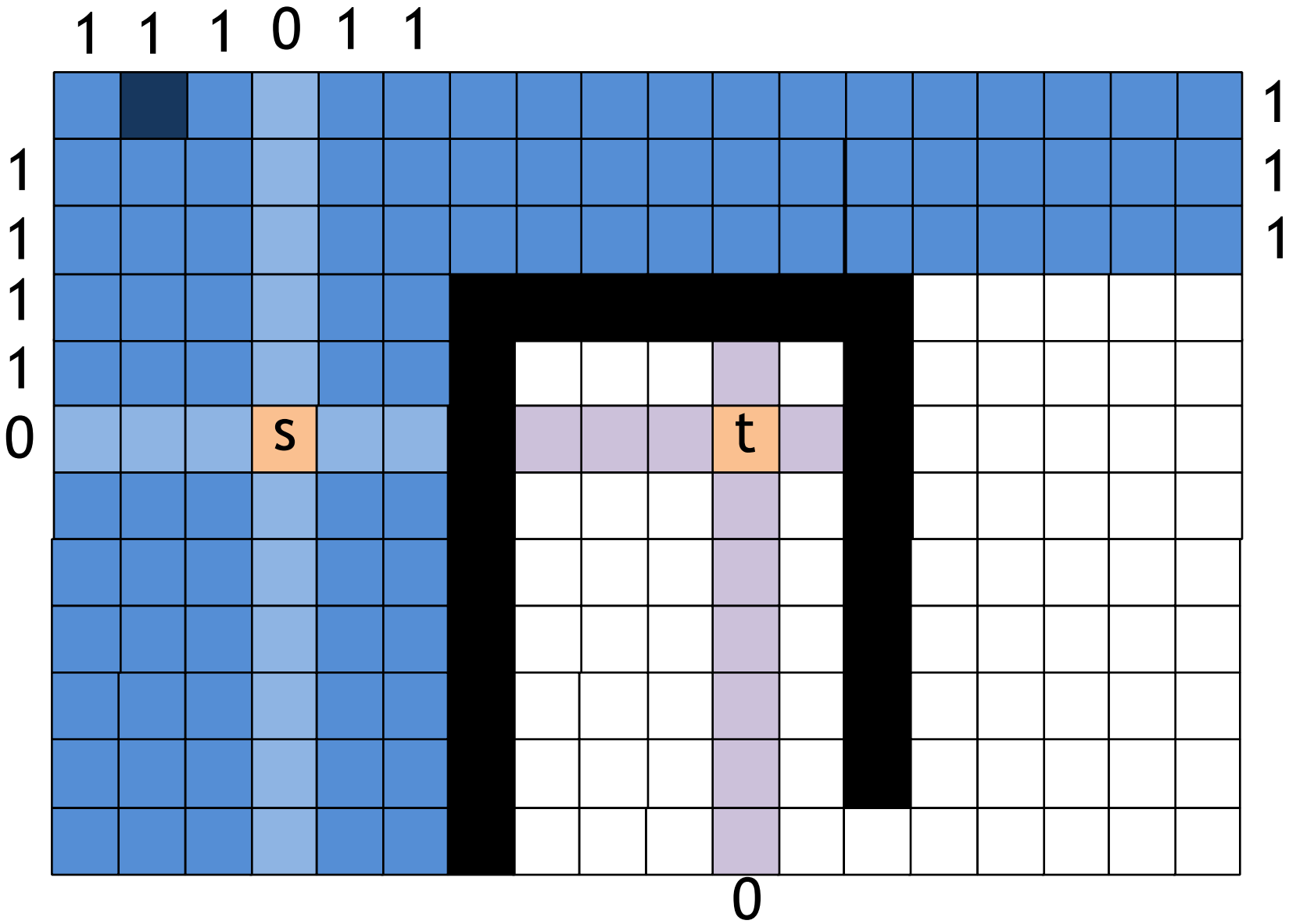
Source Line Probe (Level 1)



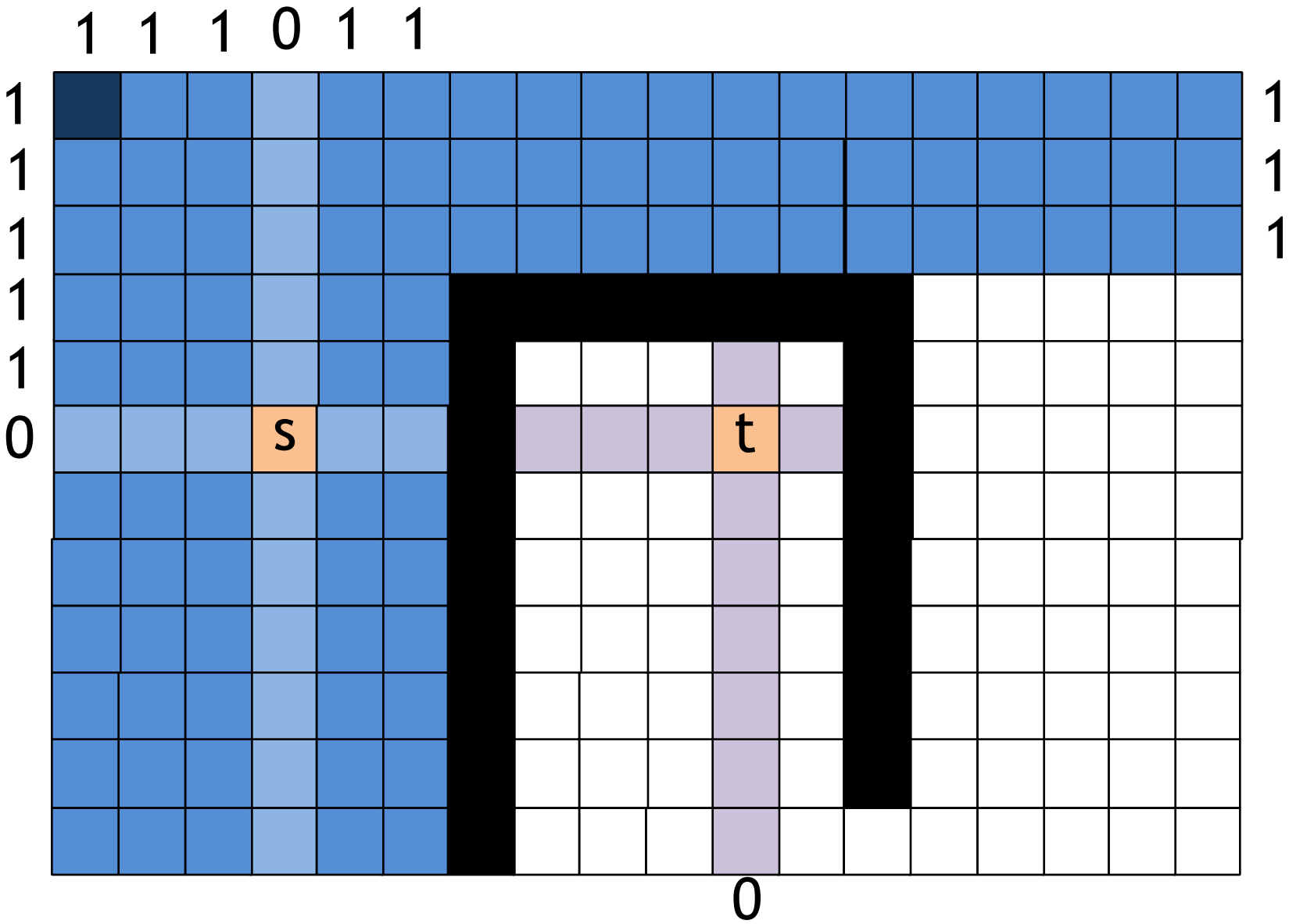
Source Line Probe (Level 1)



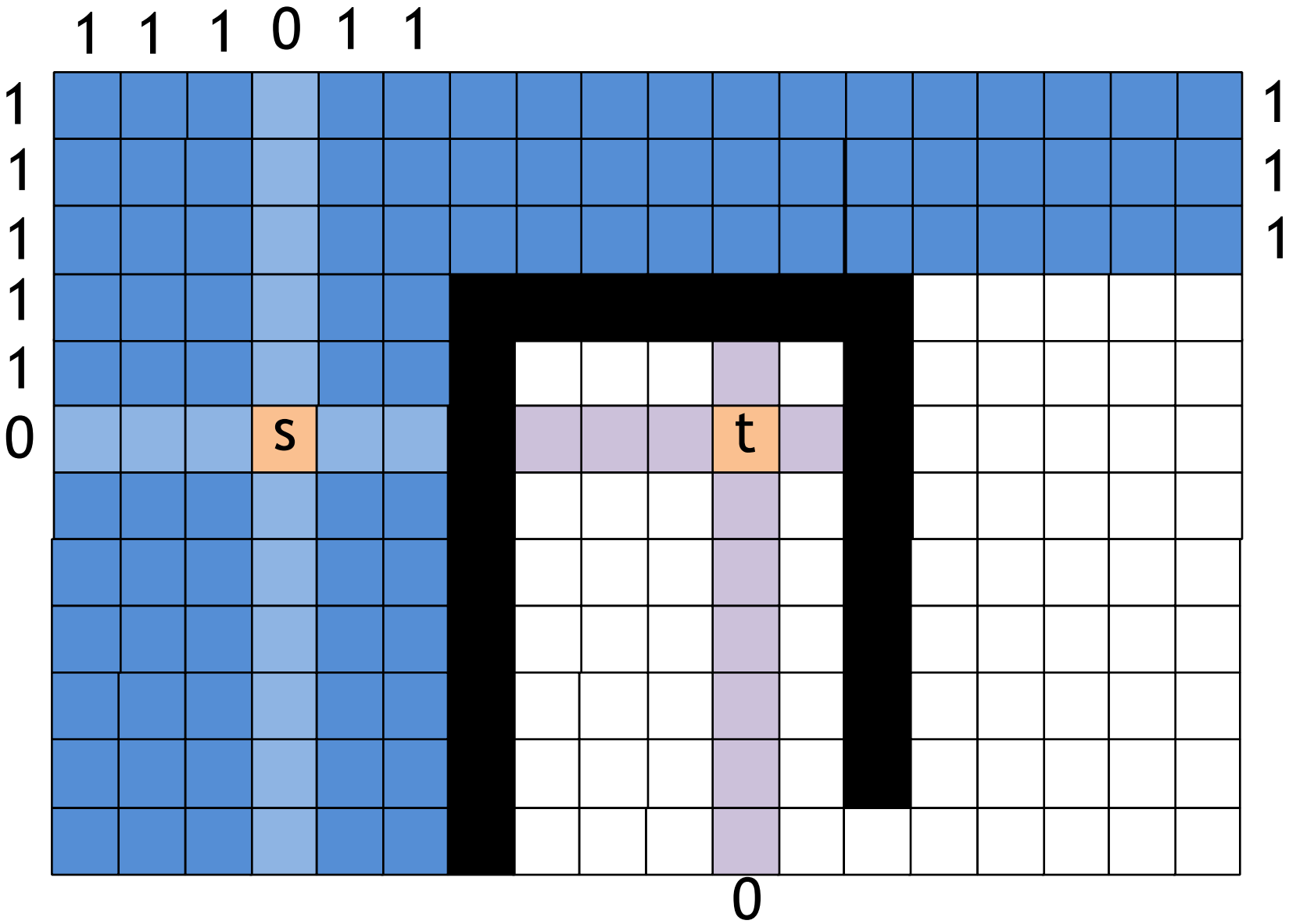
Source Line Probe (Level 1)



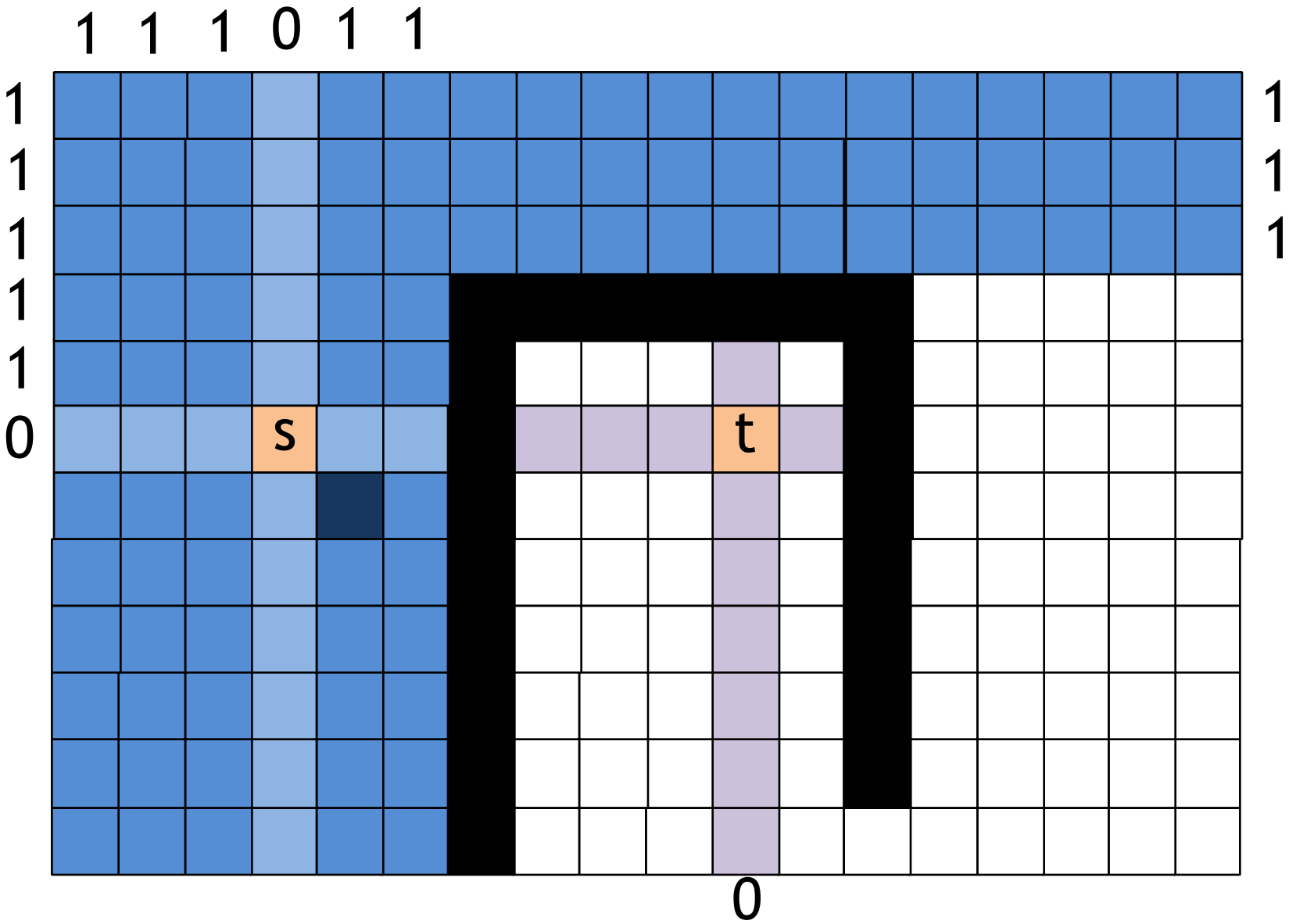
Source Line Probe (Level 1)



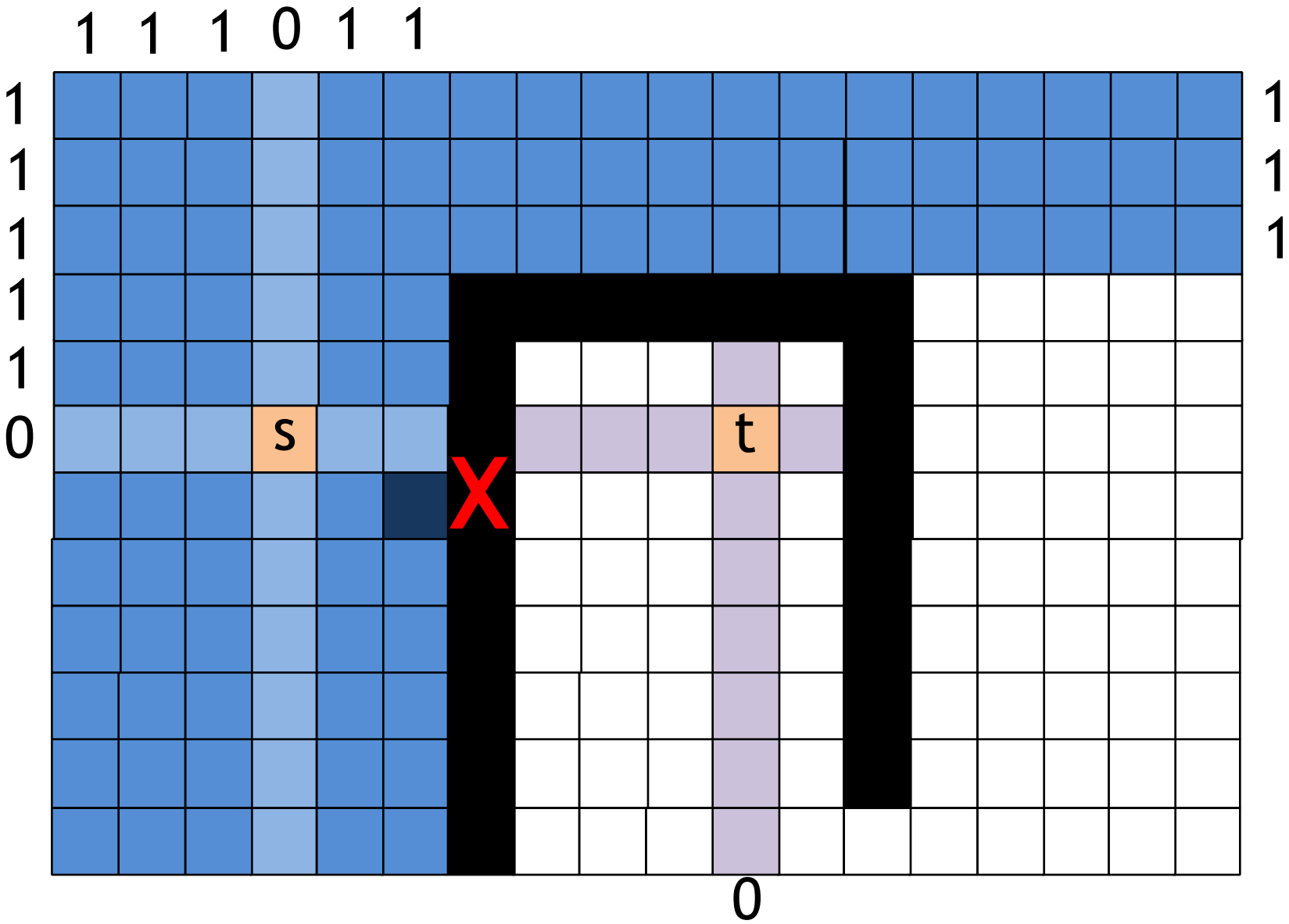
Source Line Probe (Level 1)



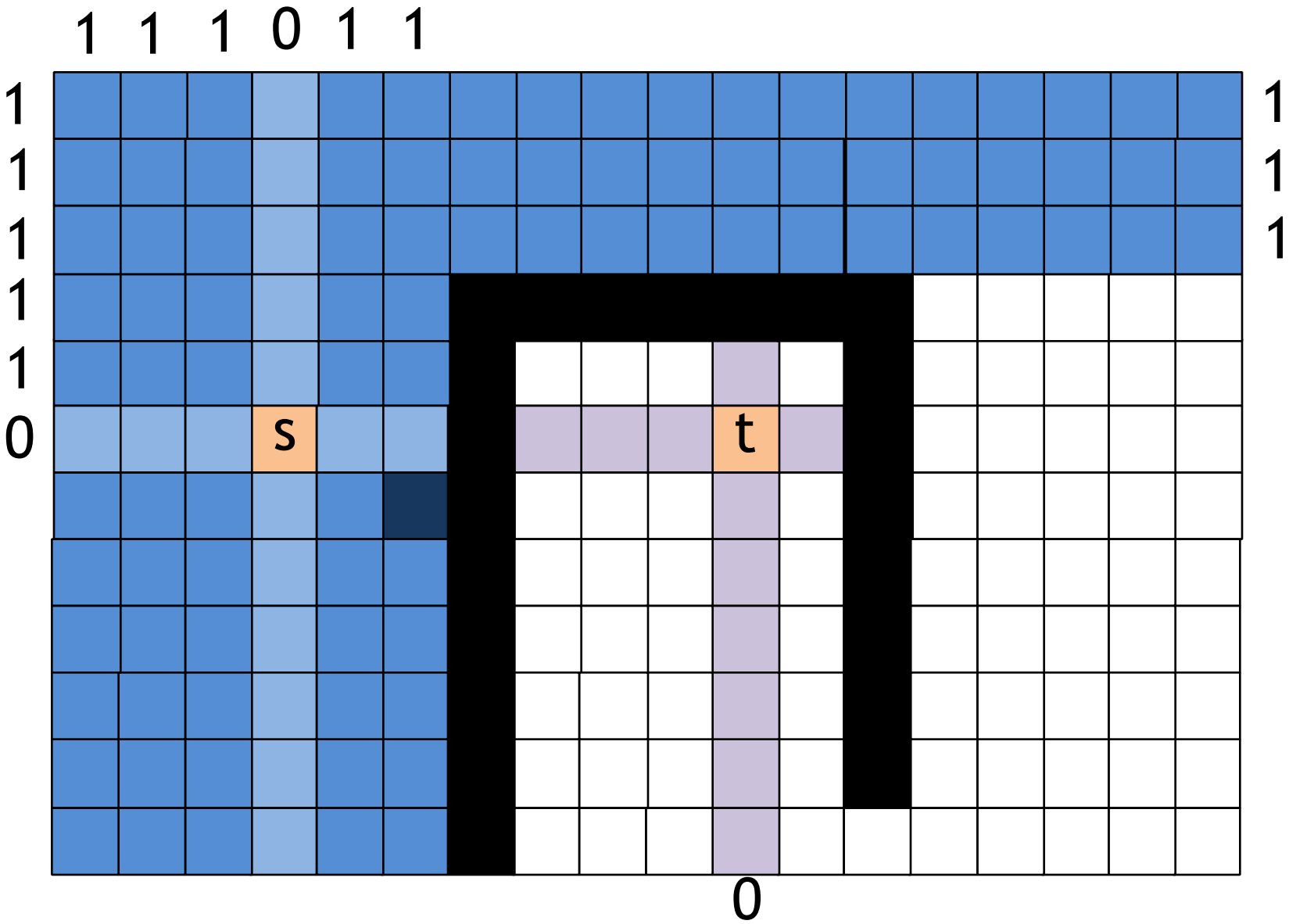
Source Line Probe (Level 1)



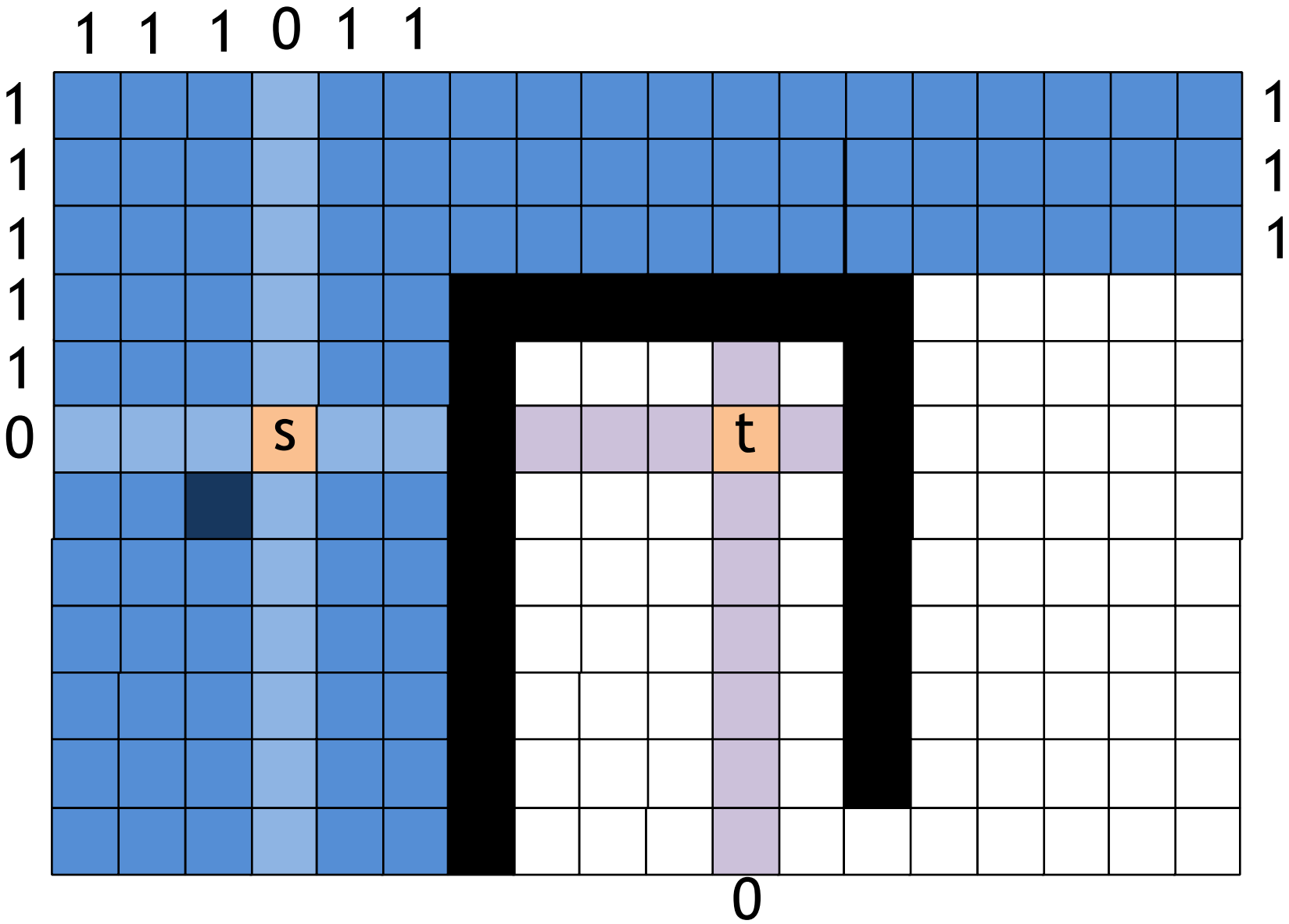
Source Line Probe (Level 1)



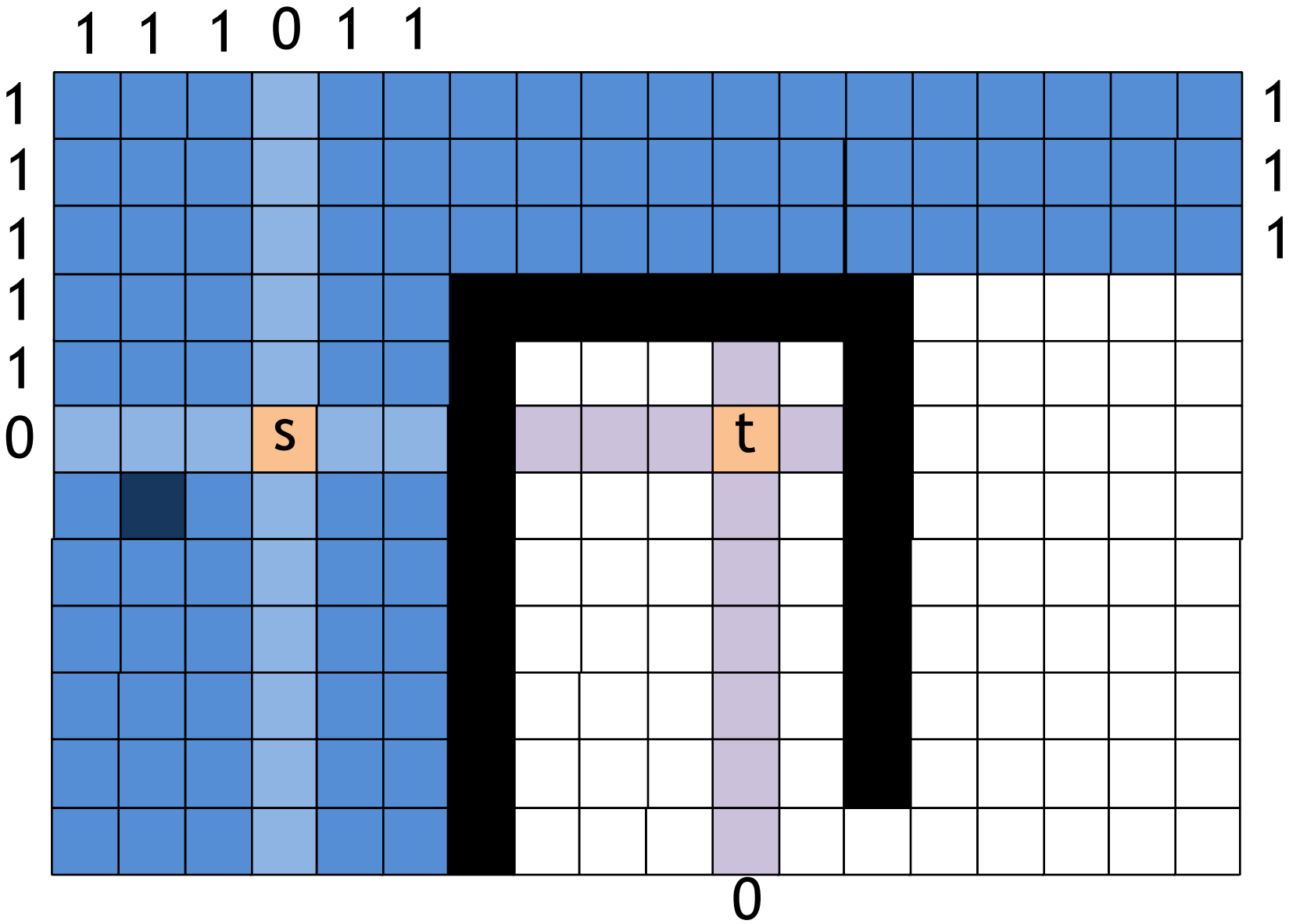
Source Line Probe (Level 1)



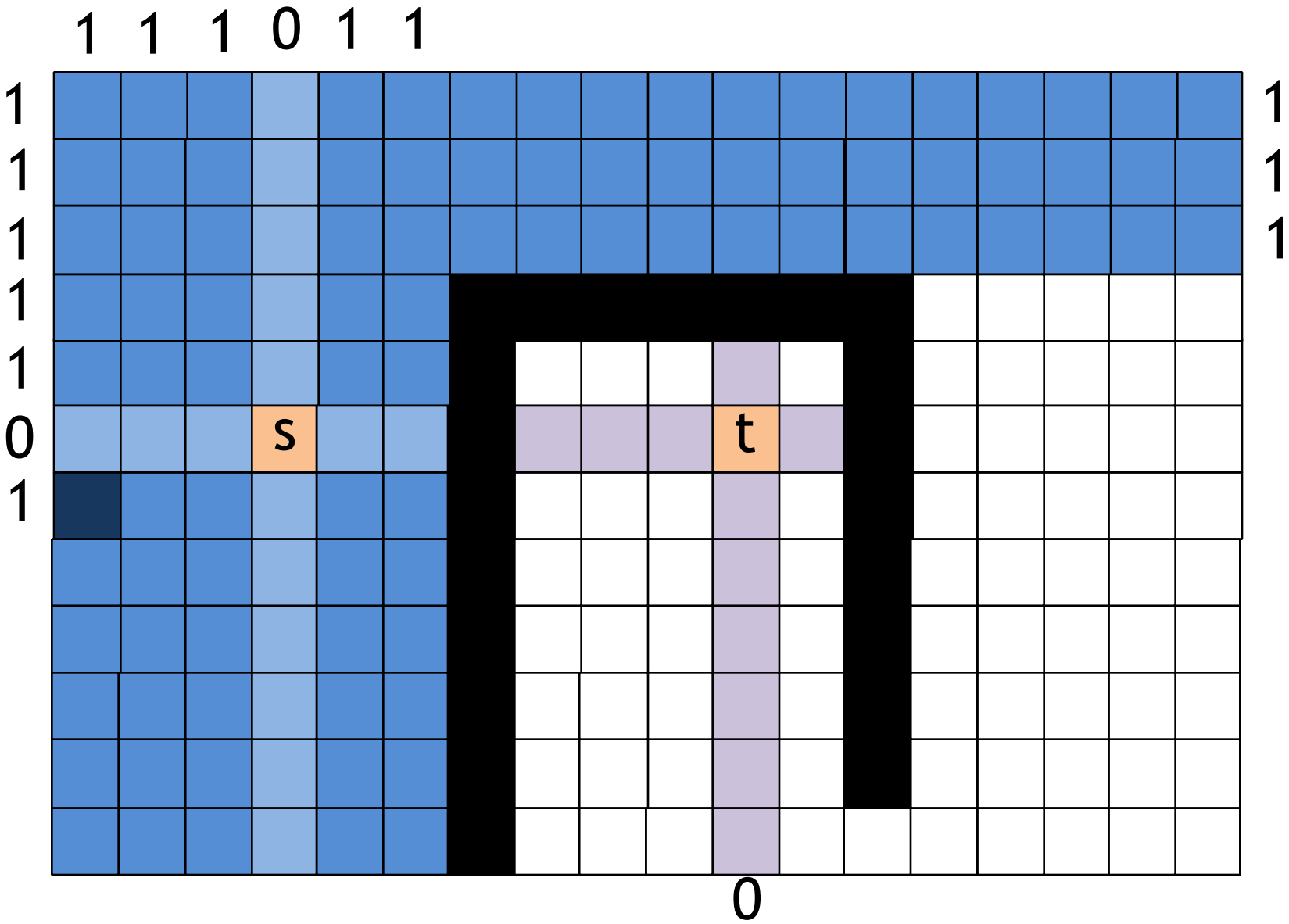
Source Line Probe (Level 1)



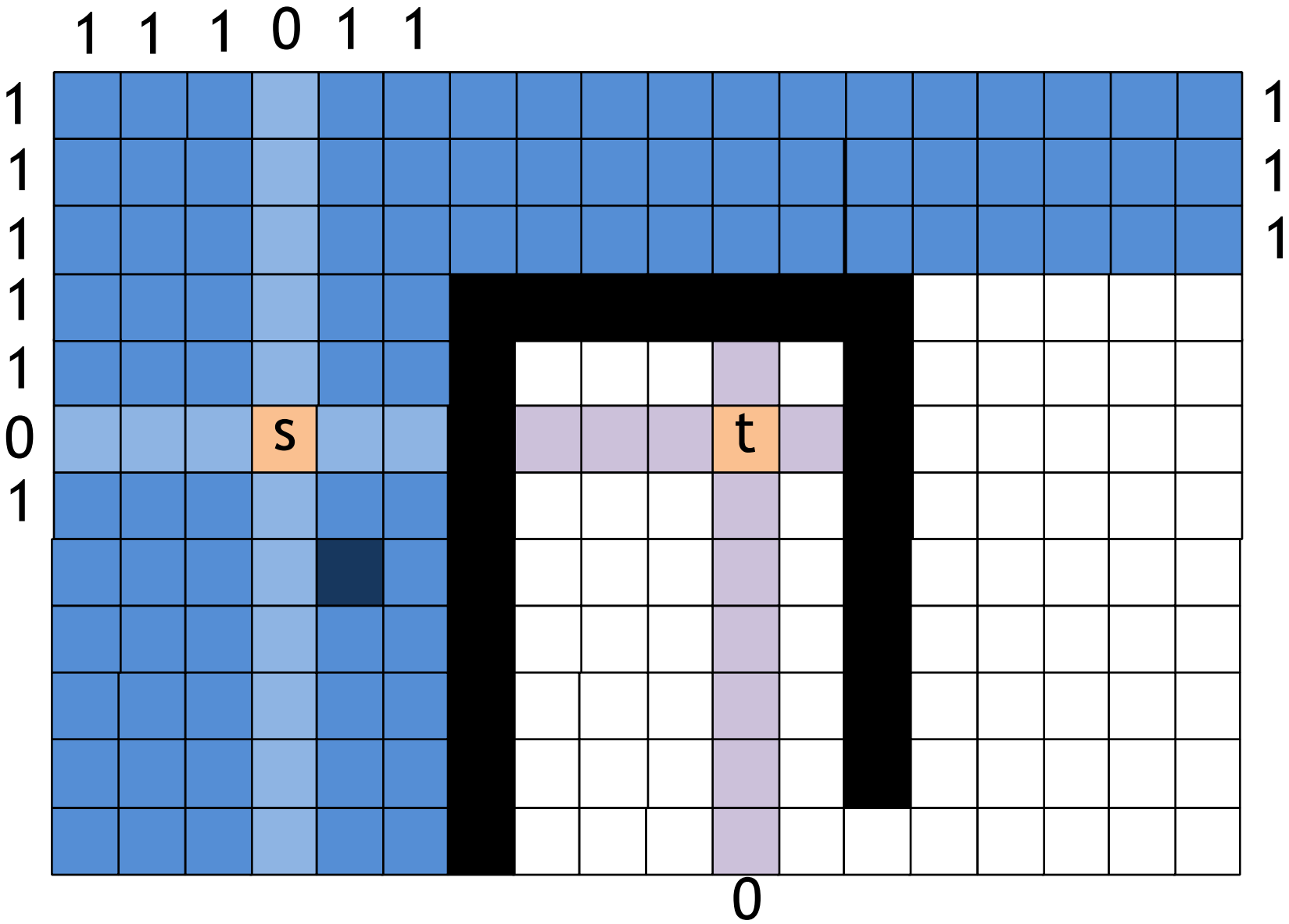
Source Line Probe (Level 1)



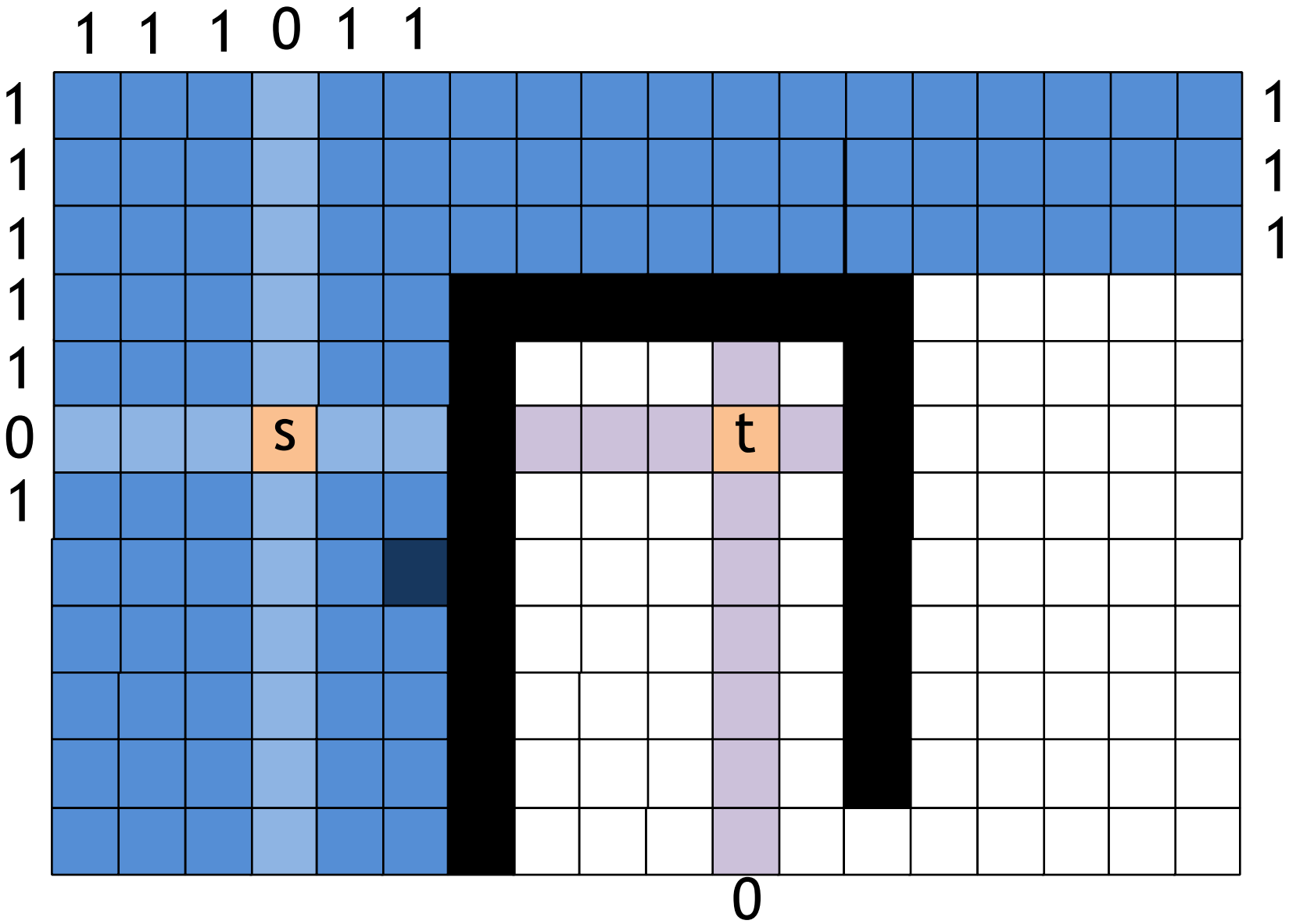
Source Line Probe (Level 1)



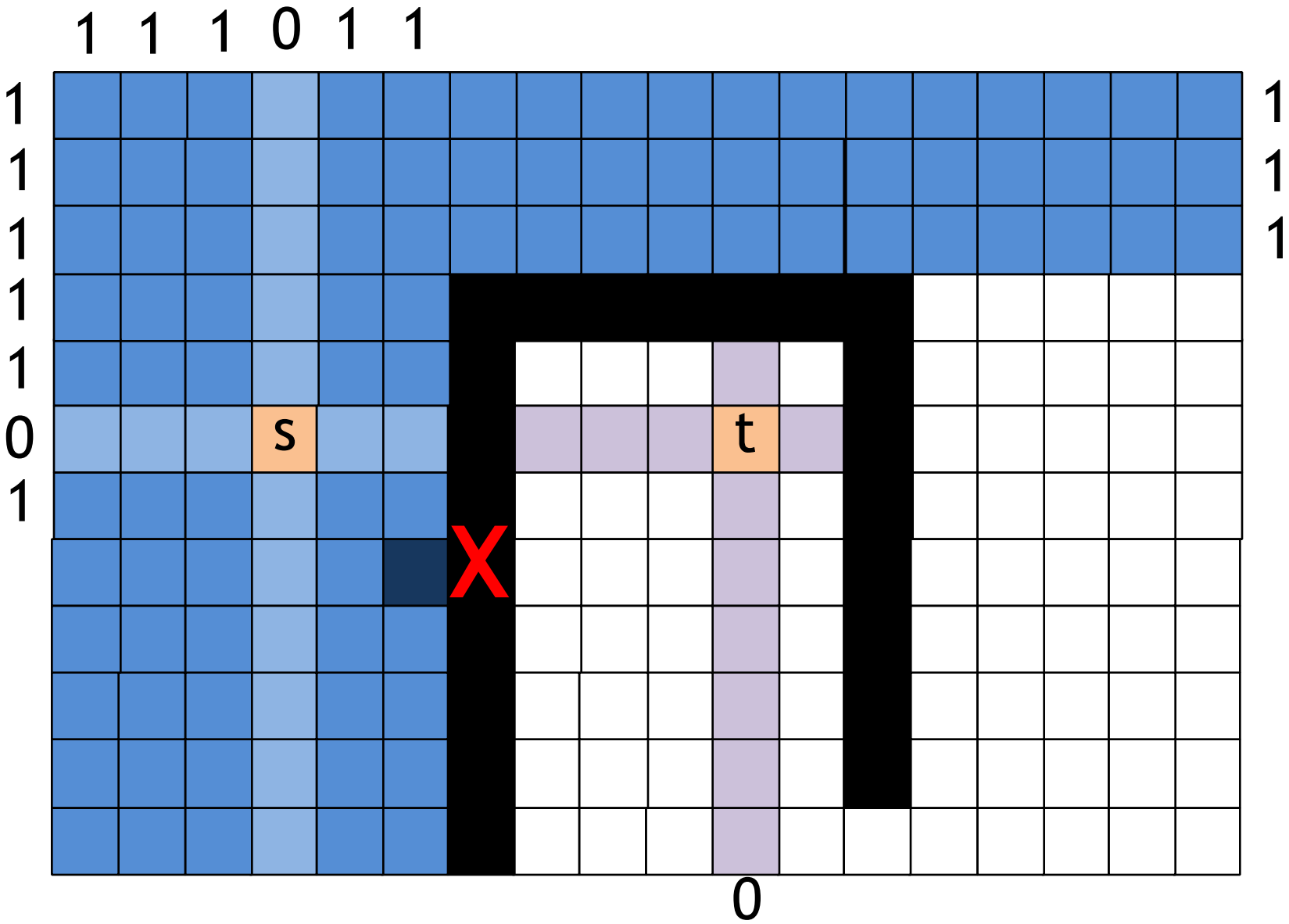
Source Line Probe (Level 1)



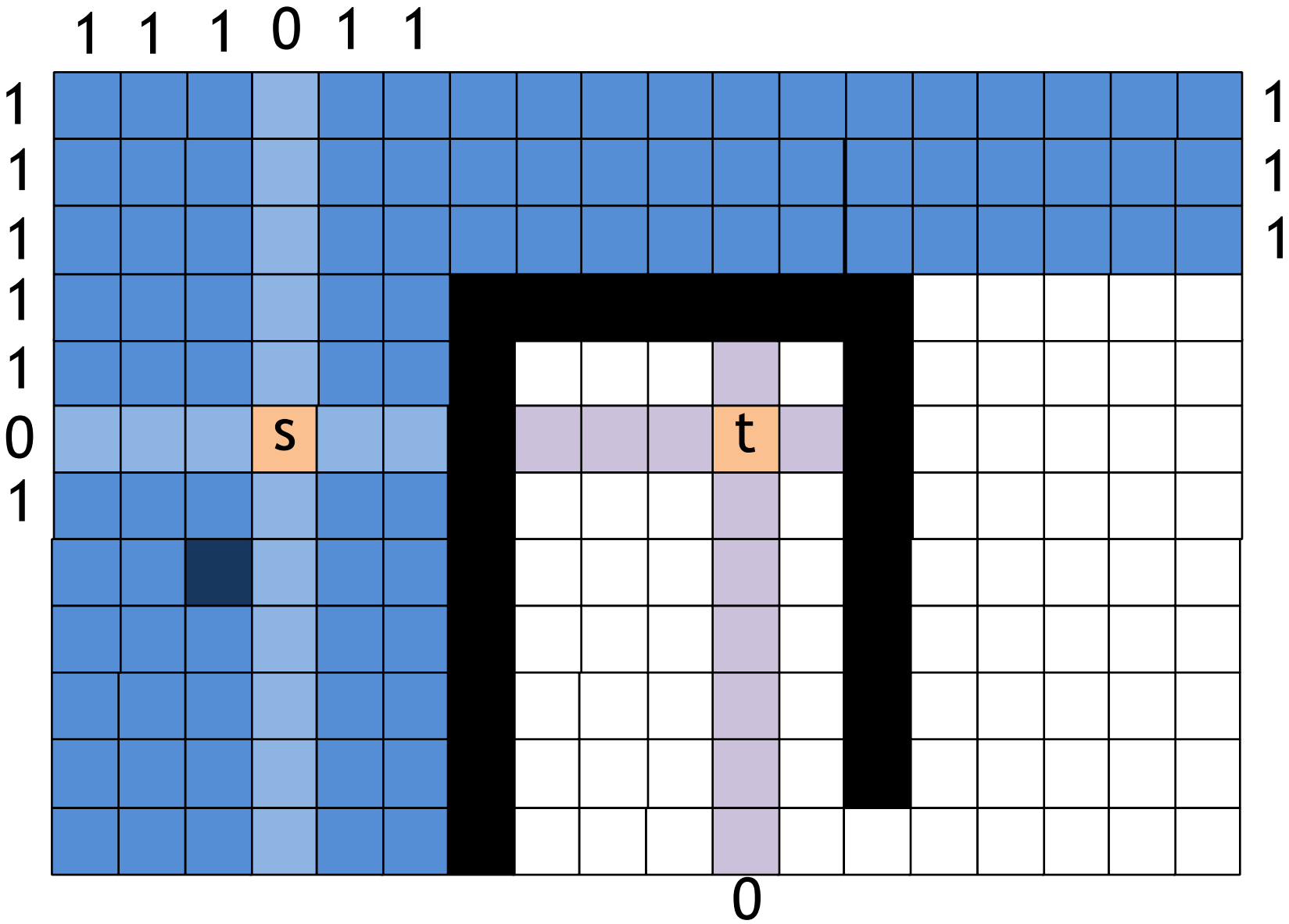
Source Line Probe (Level 1)



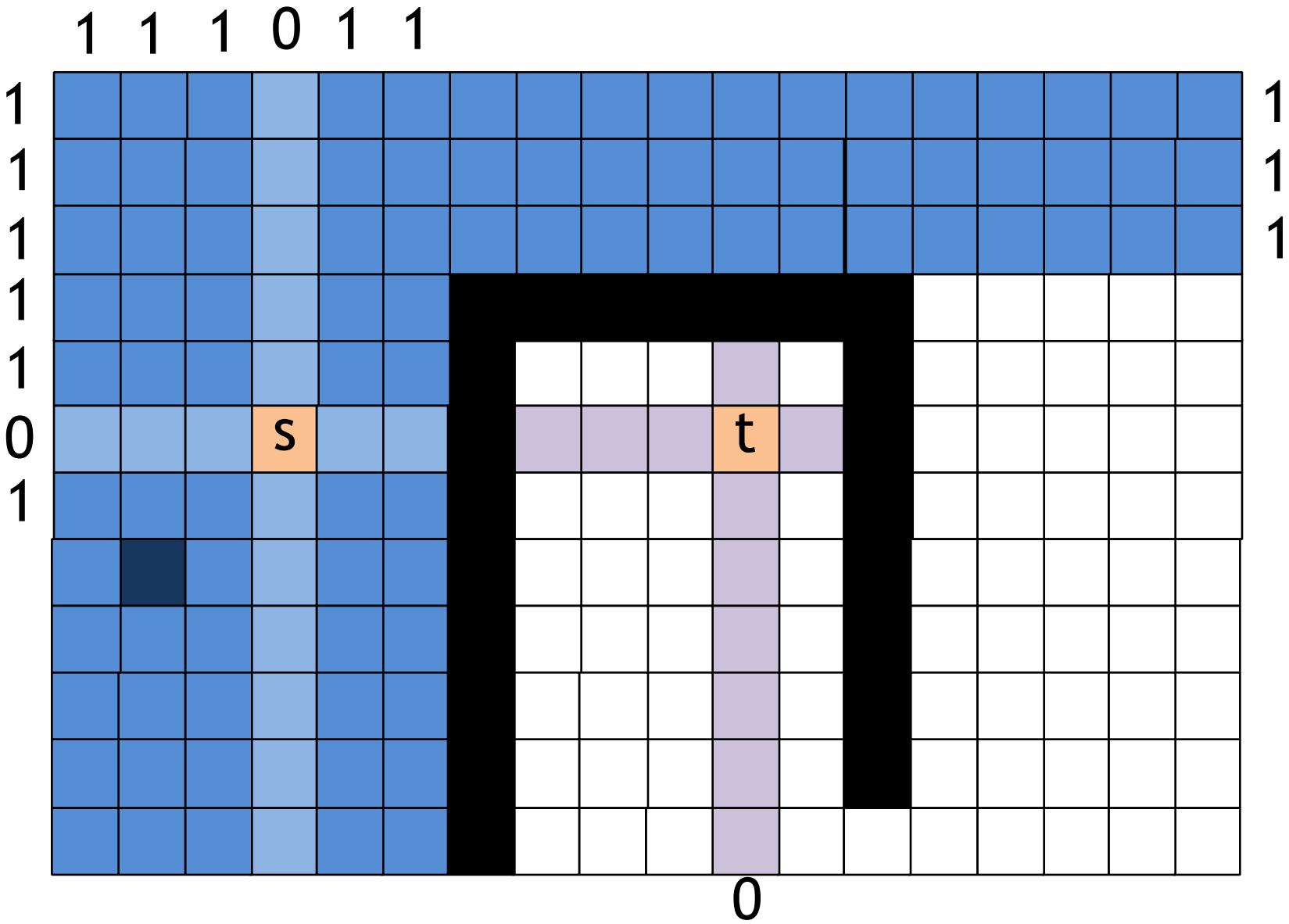
Source Line Probe (Level 1)



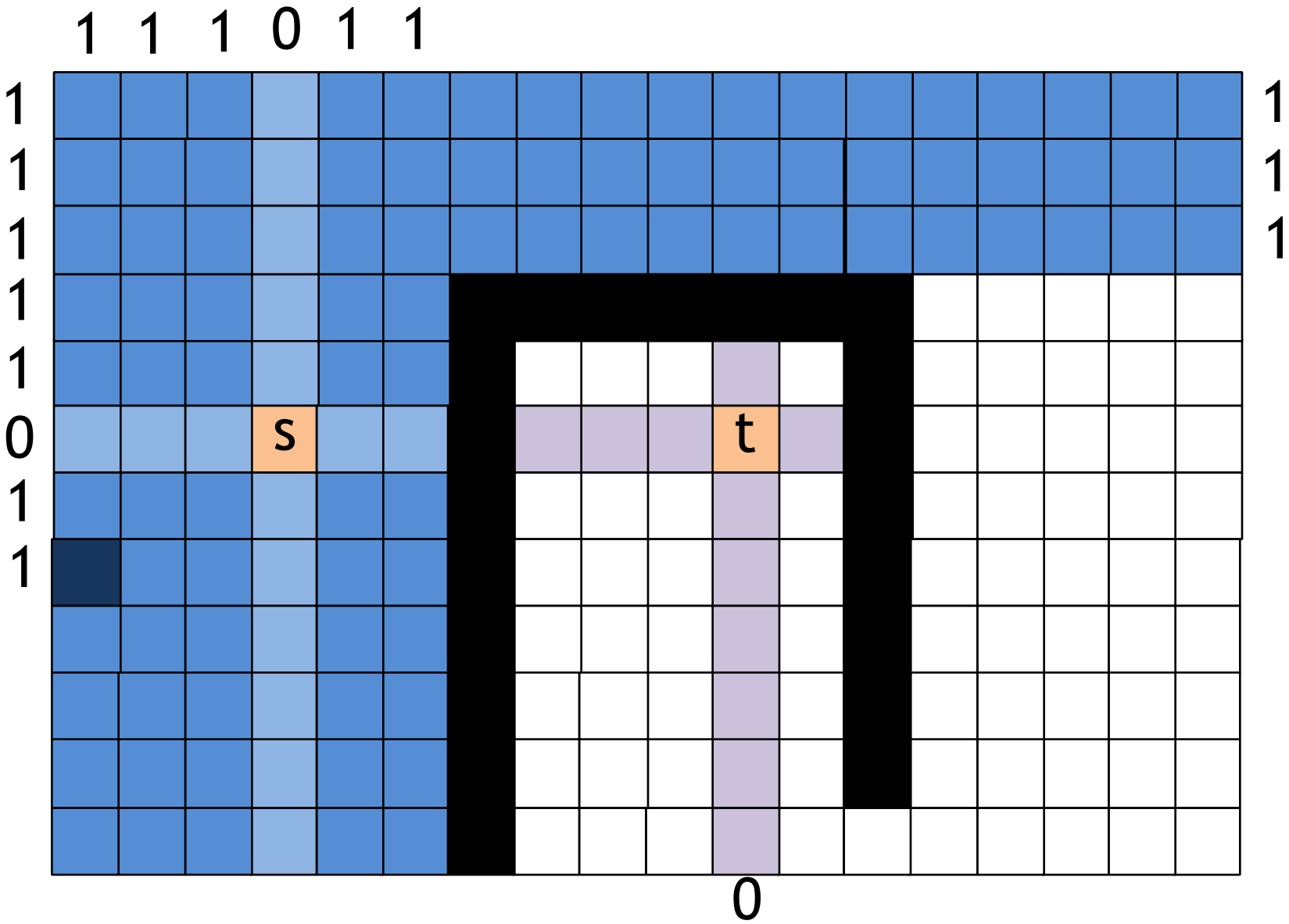
Source Line Probe (Level 1)



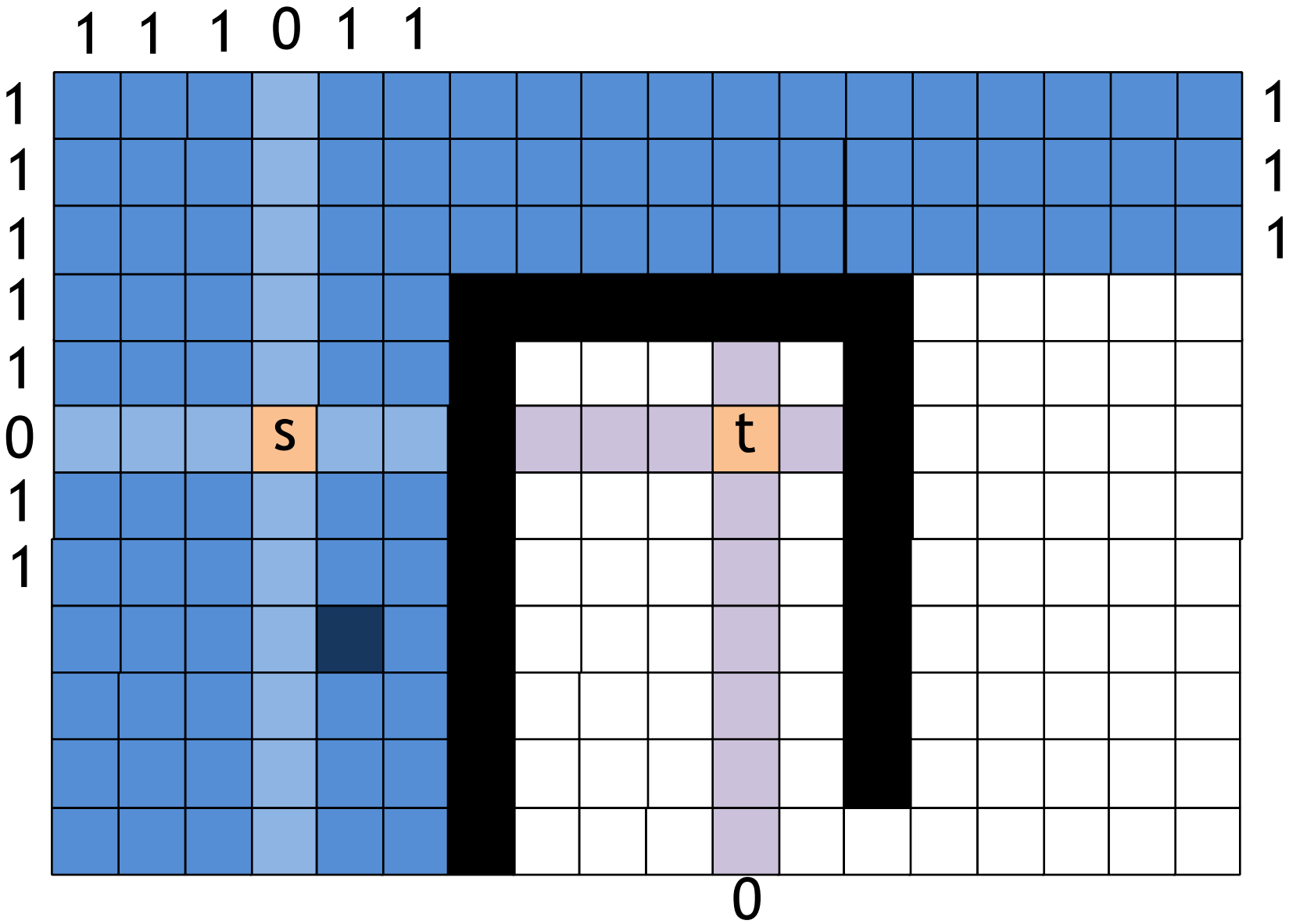
Source Line Probe (Level 1)



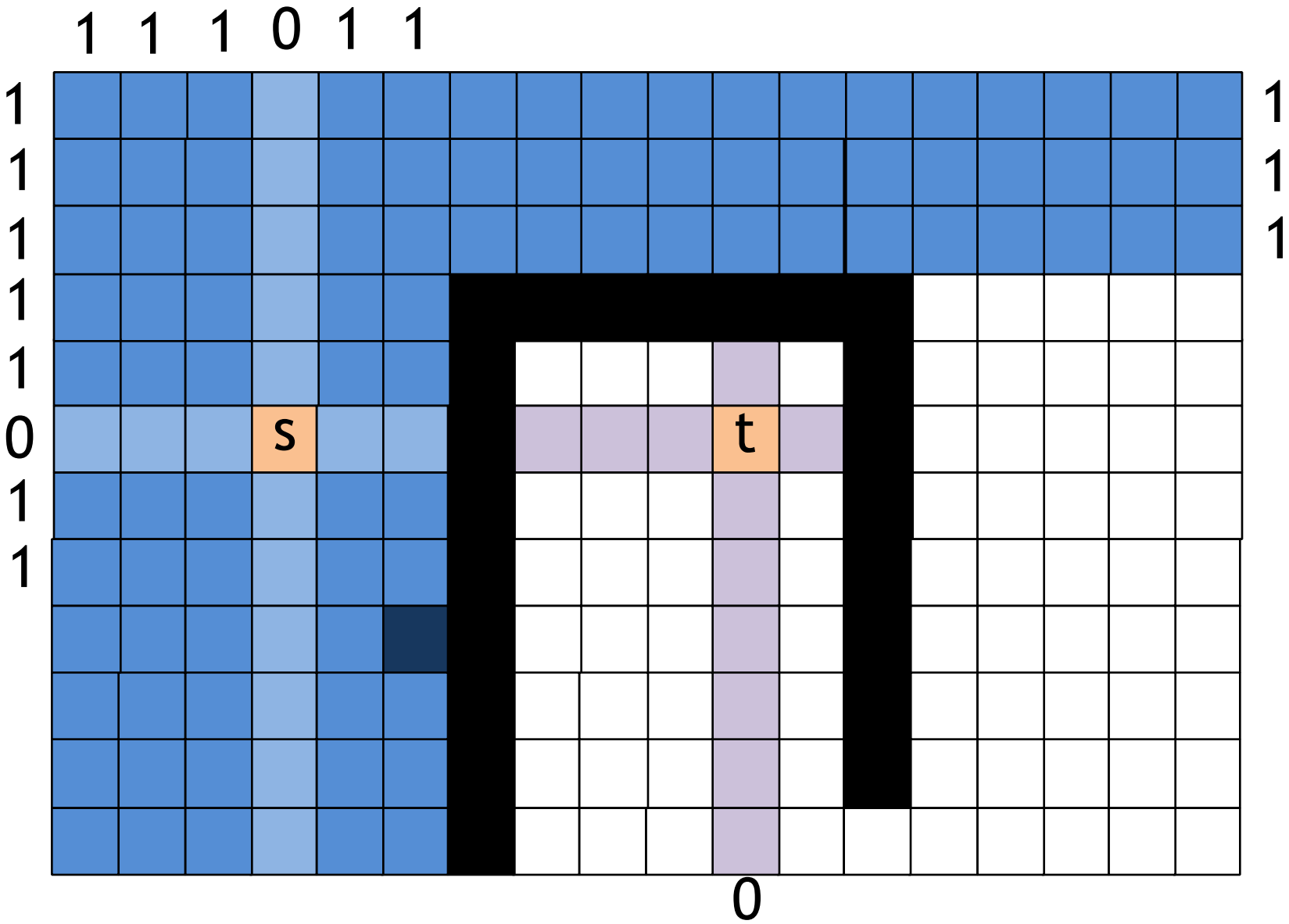
Source Line Probe (Level 1)



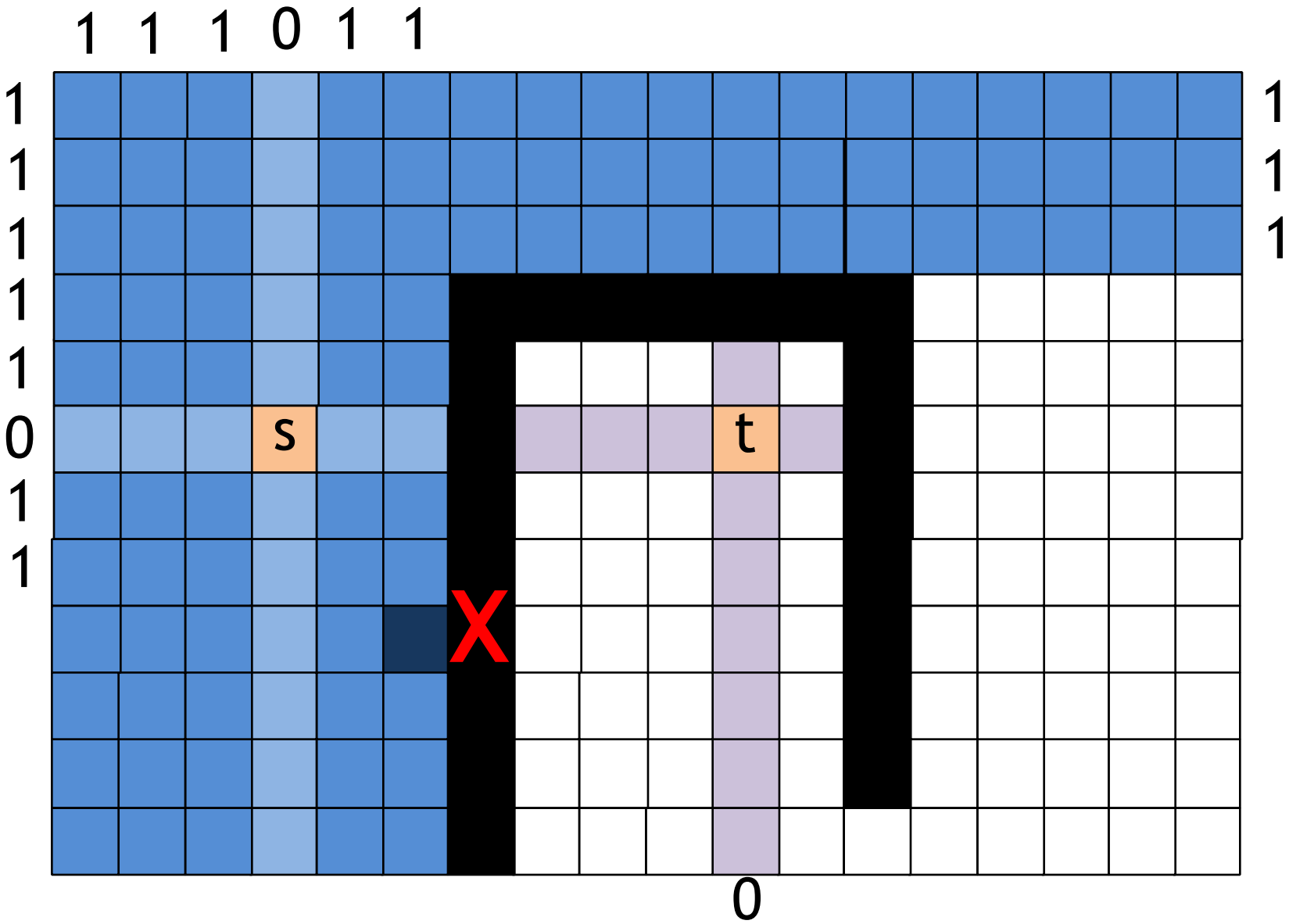
Source Line Probe (Level 1)



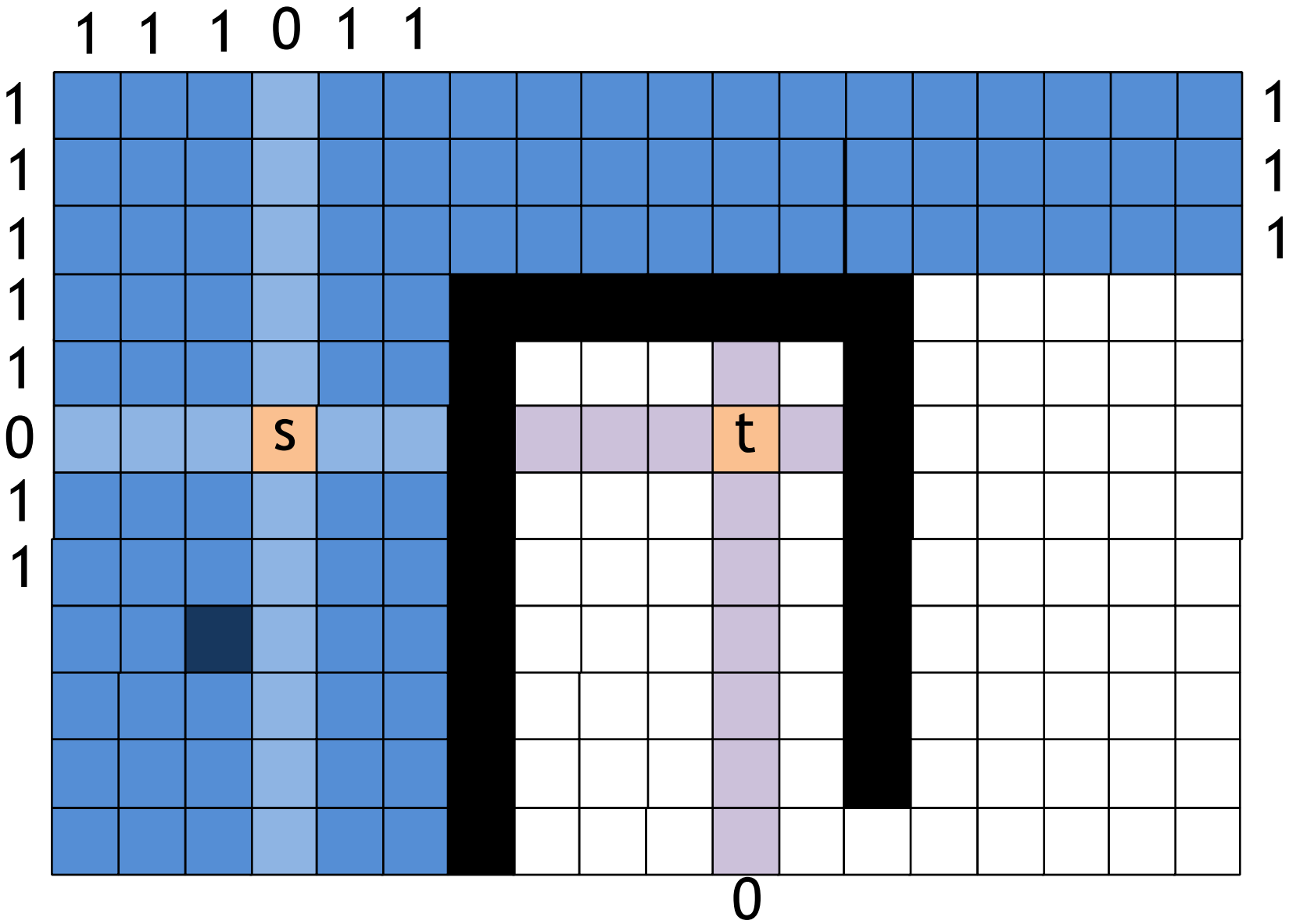
Source Line Probe (Level 1)



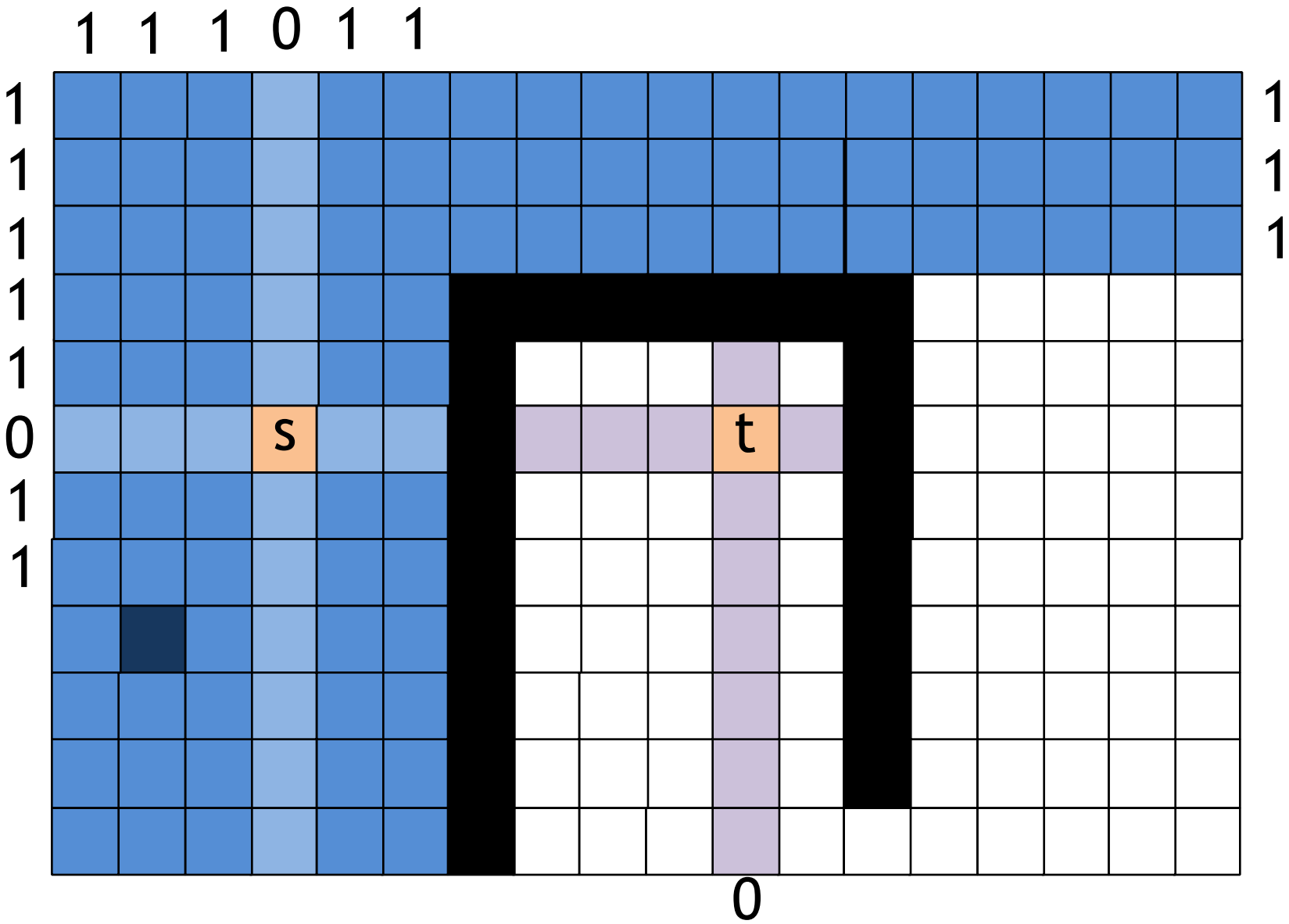
Source Line Probe (Level 1)



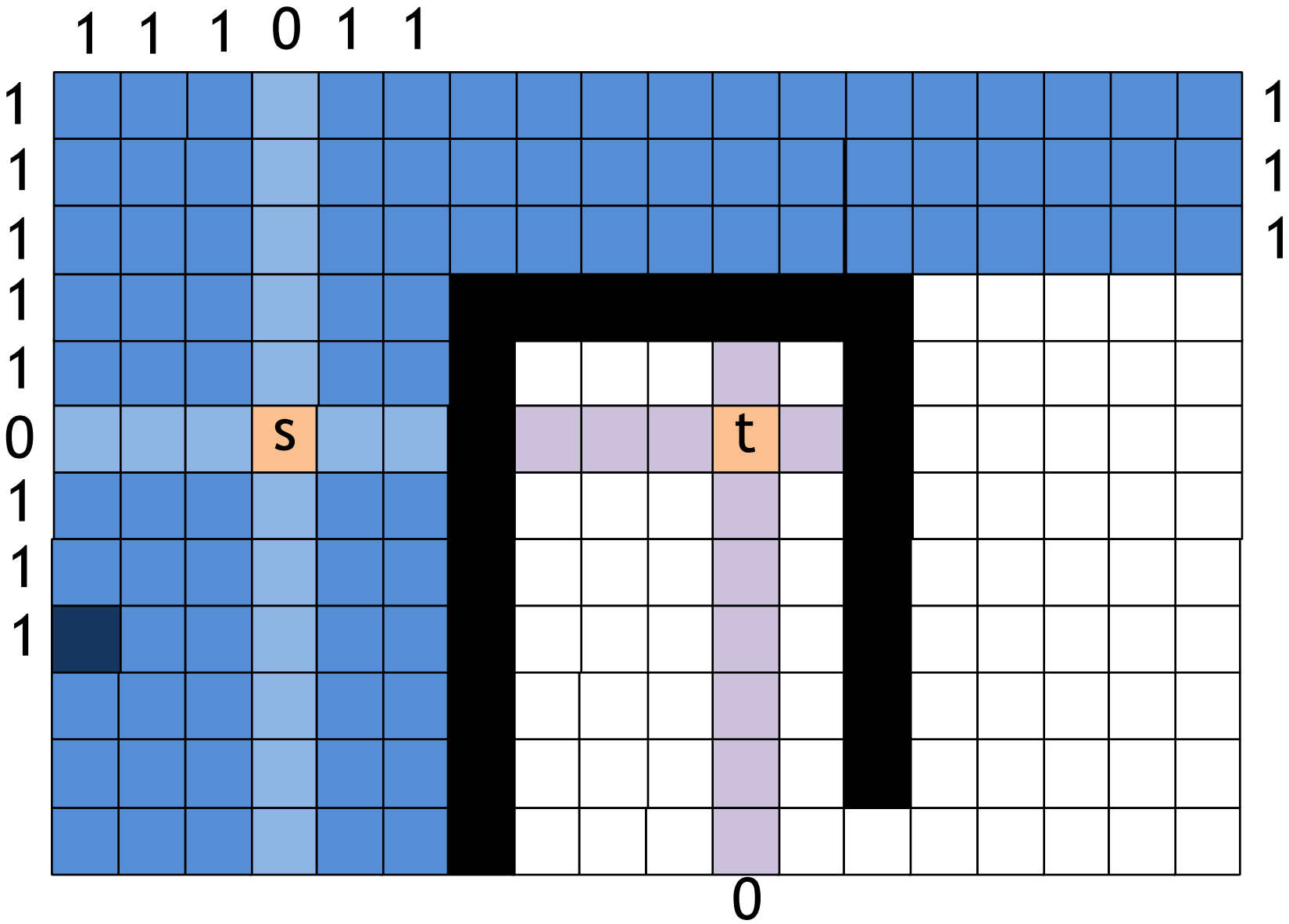
Source Line Probe (Level 1)



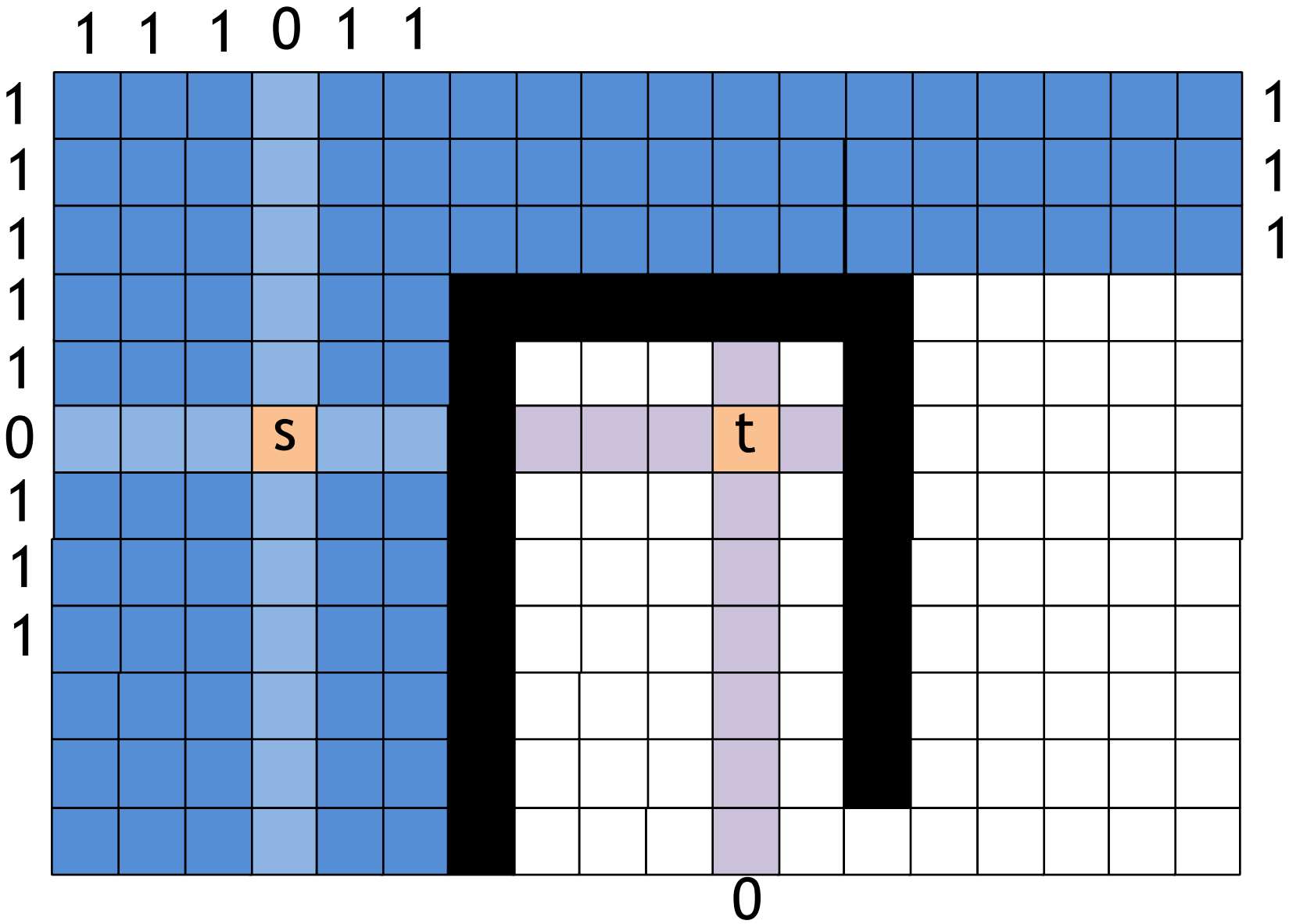
Source Line Probe (Level 1)



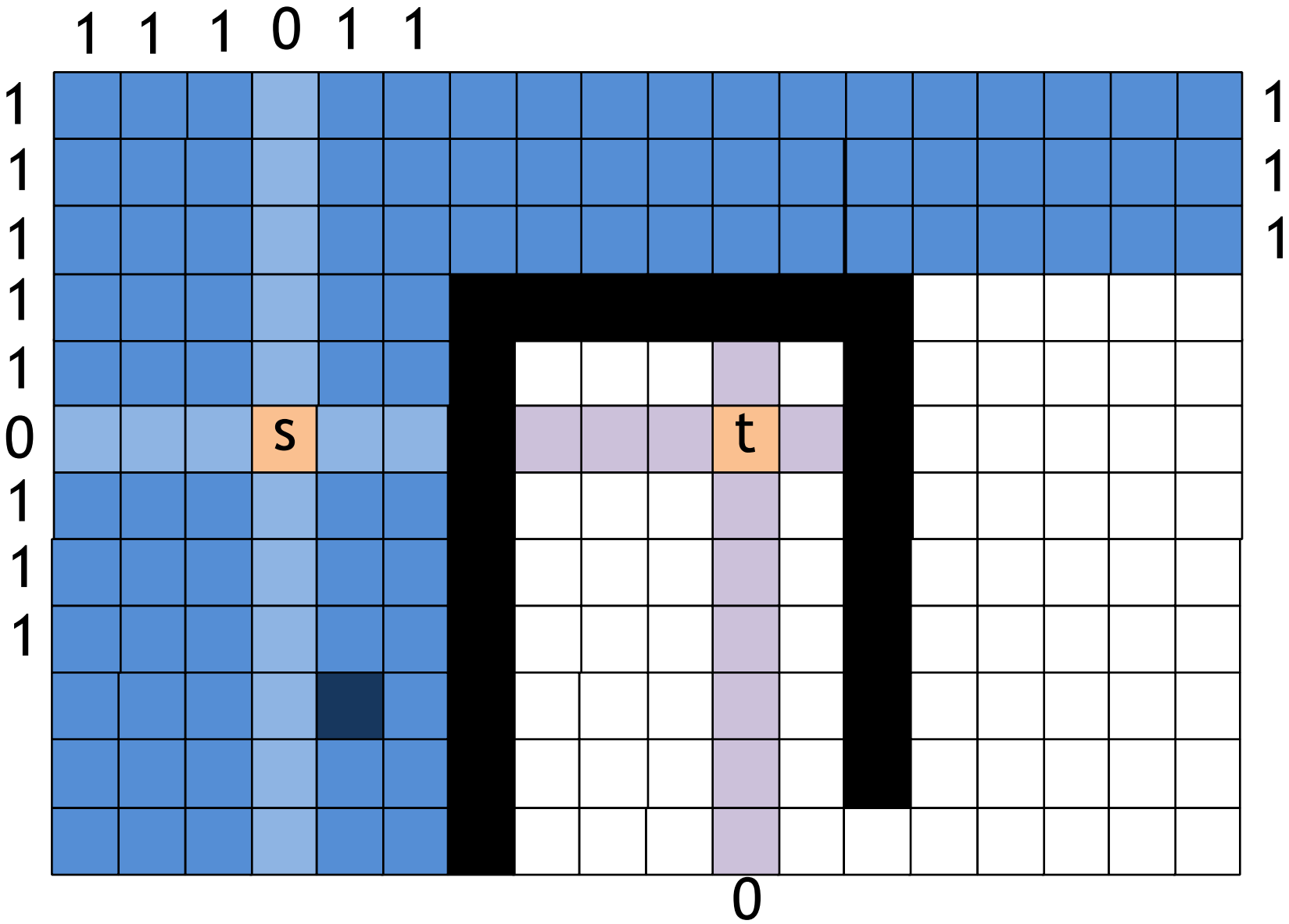
Source Line Probe (Level 1)



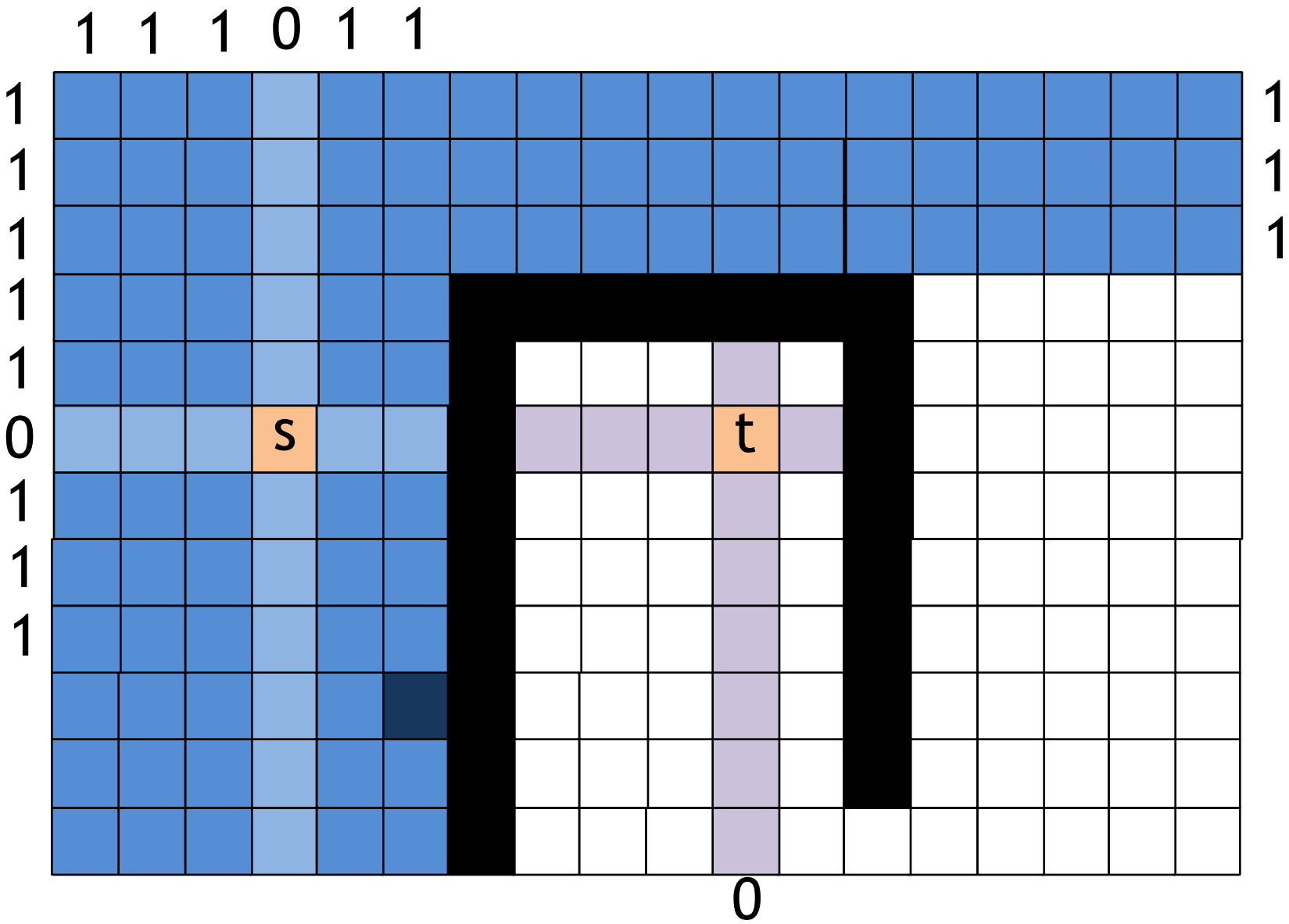
Source Line Probe (Level 1)



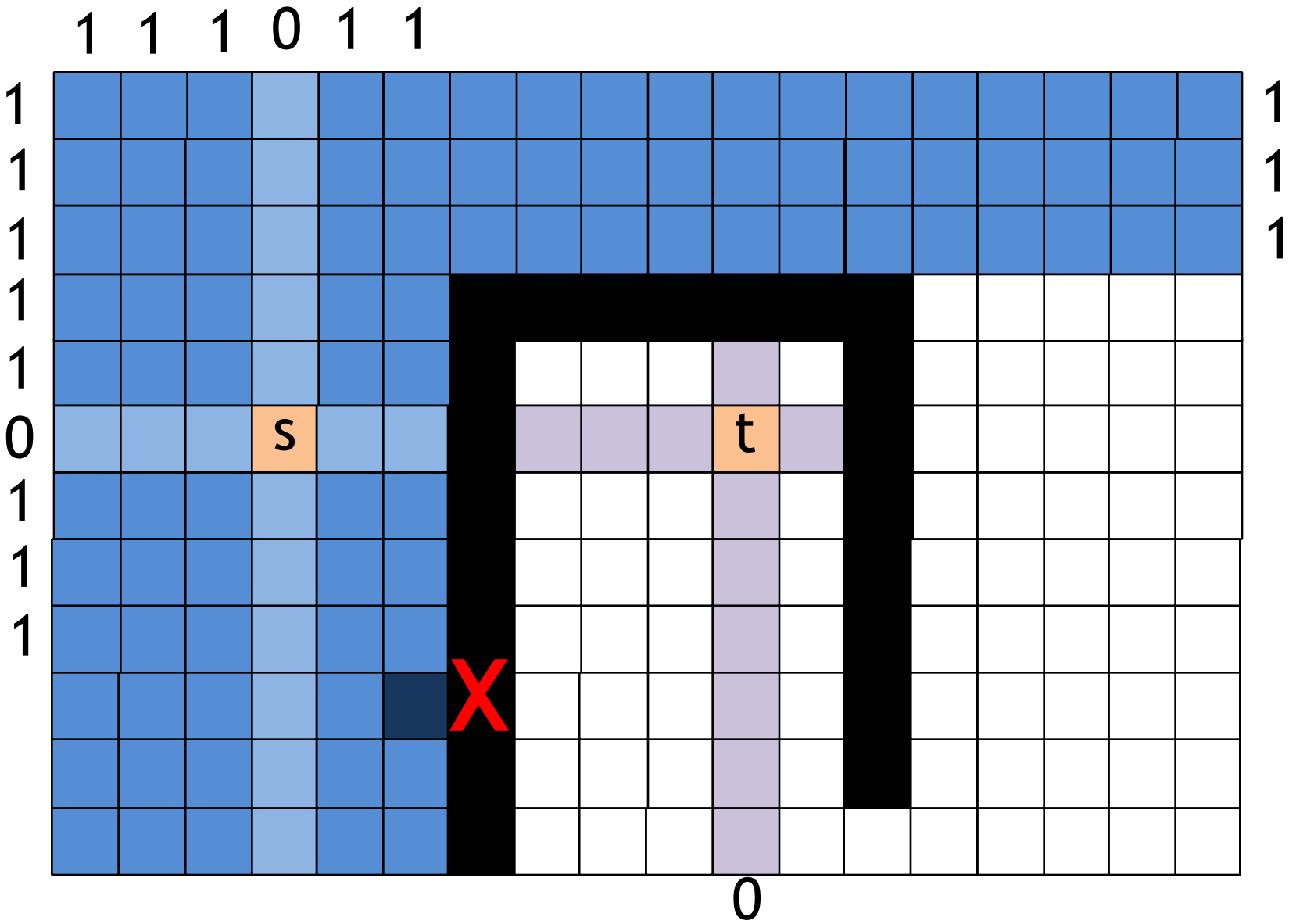
Source Line Probe (Level 1)



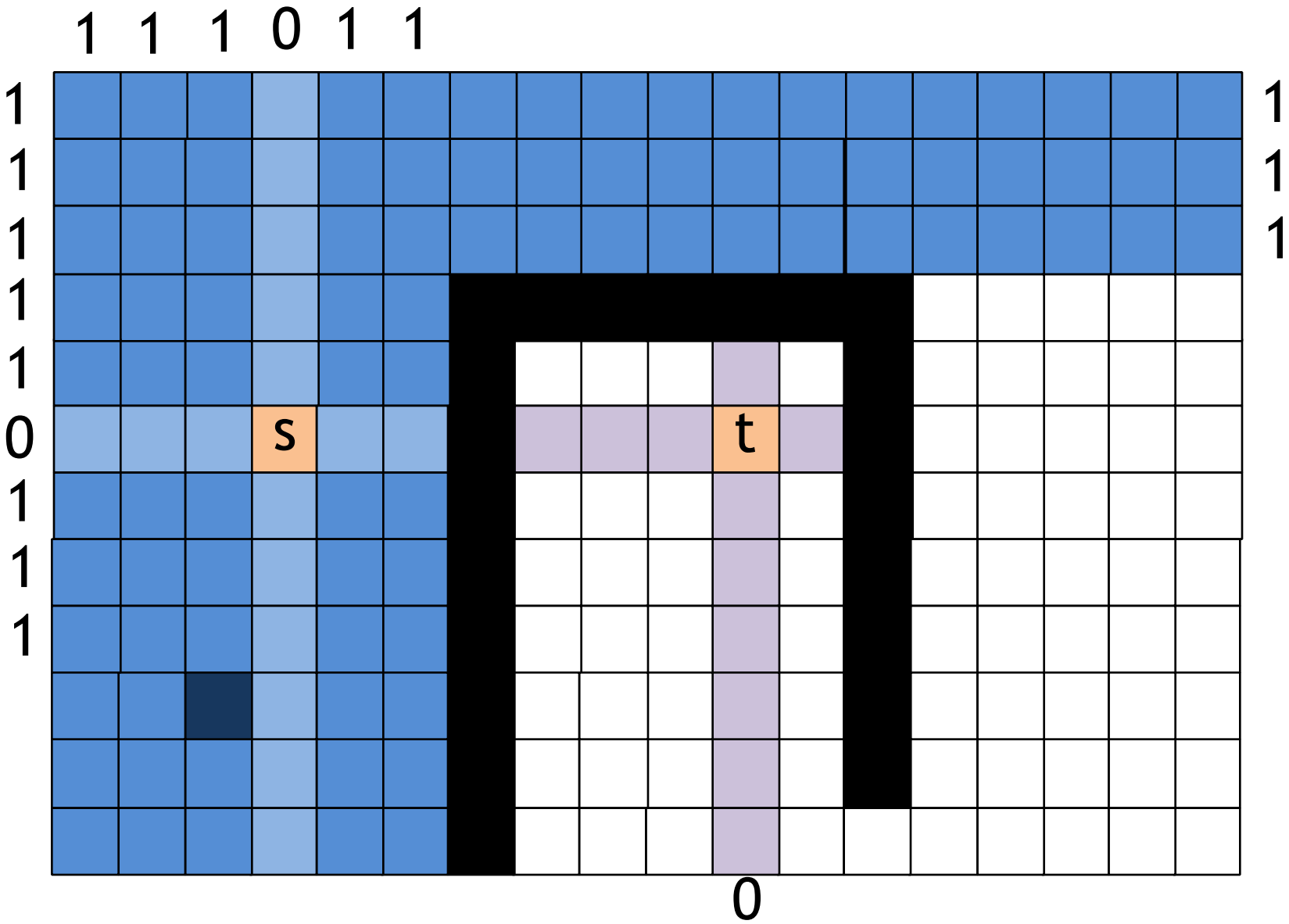
Source Line Probe (Level 1)



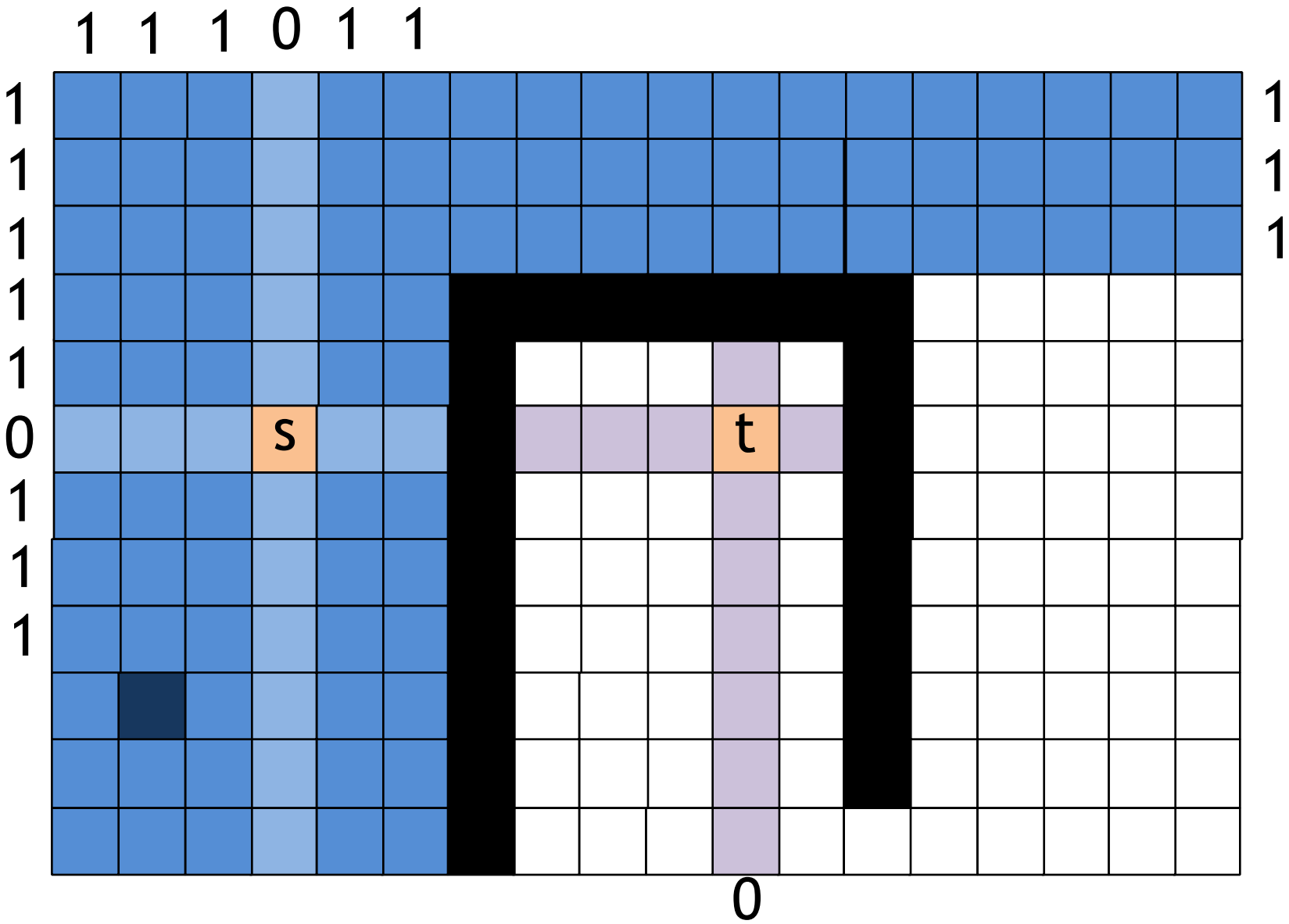
Source Line Probe (Level 1)



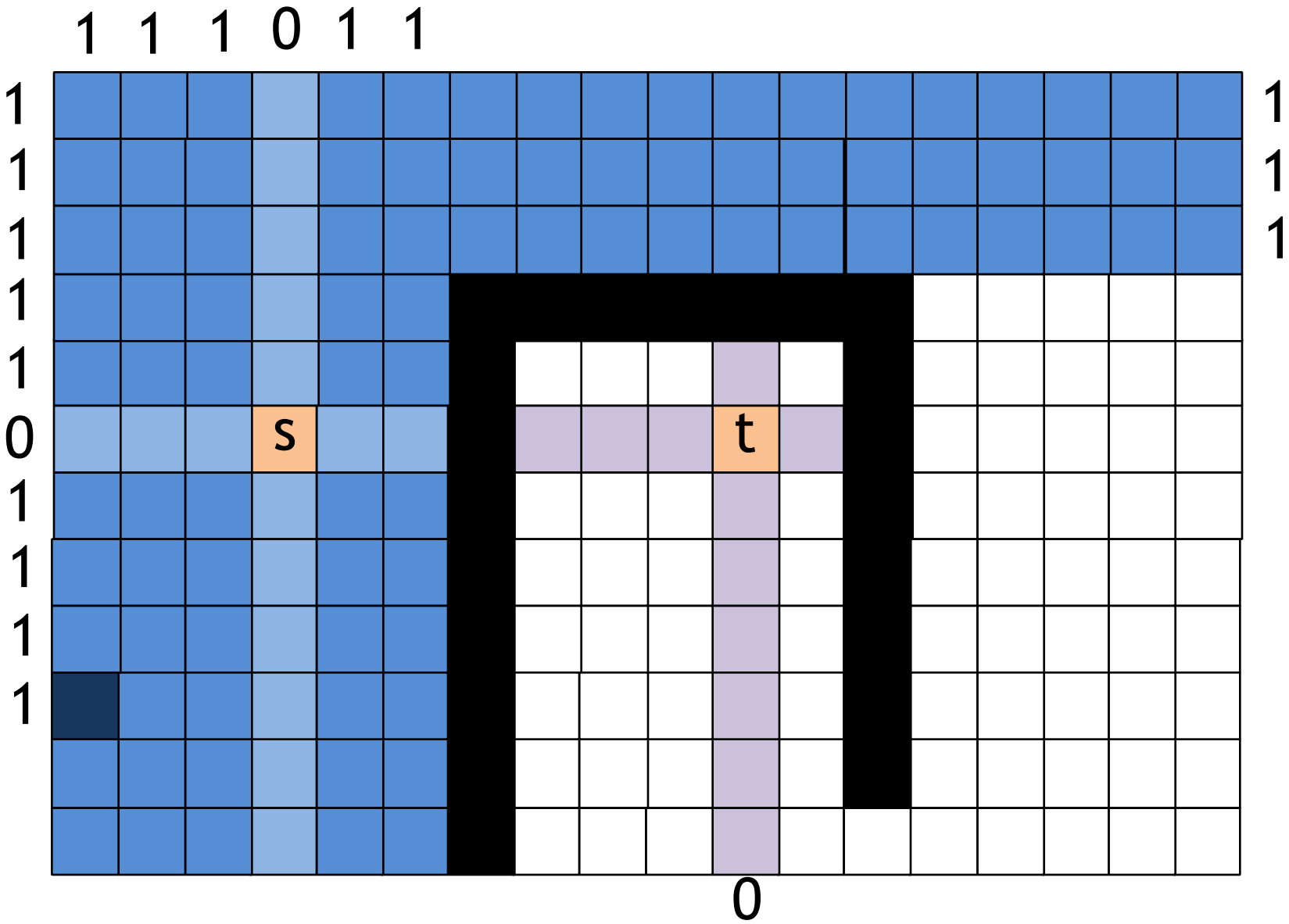
Source Line Probe (Level 1)



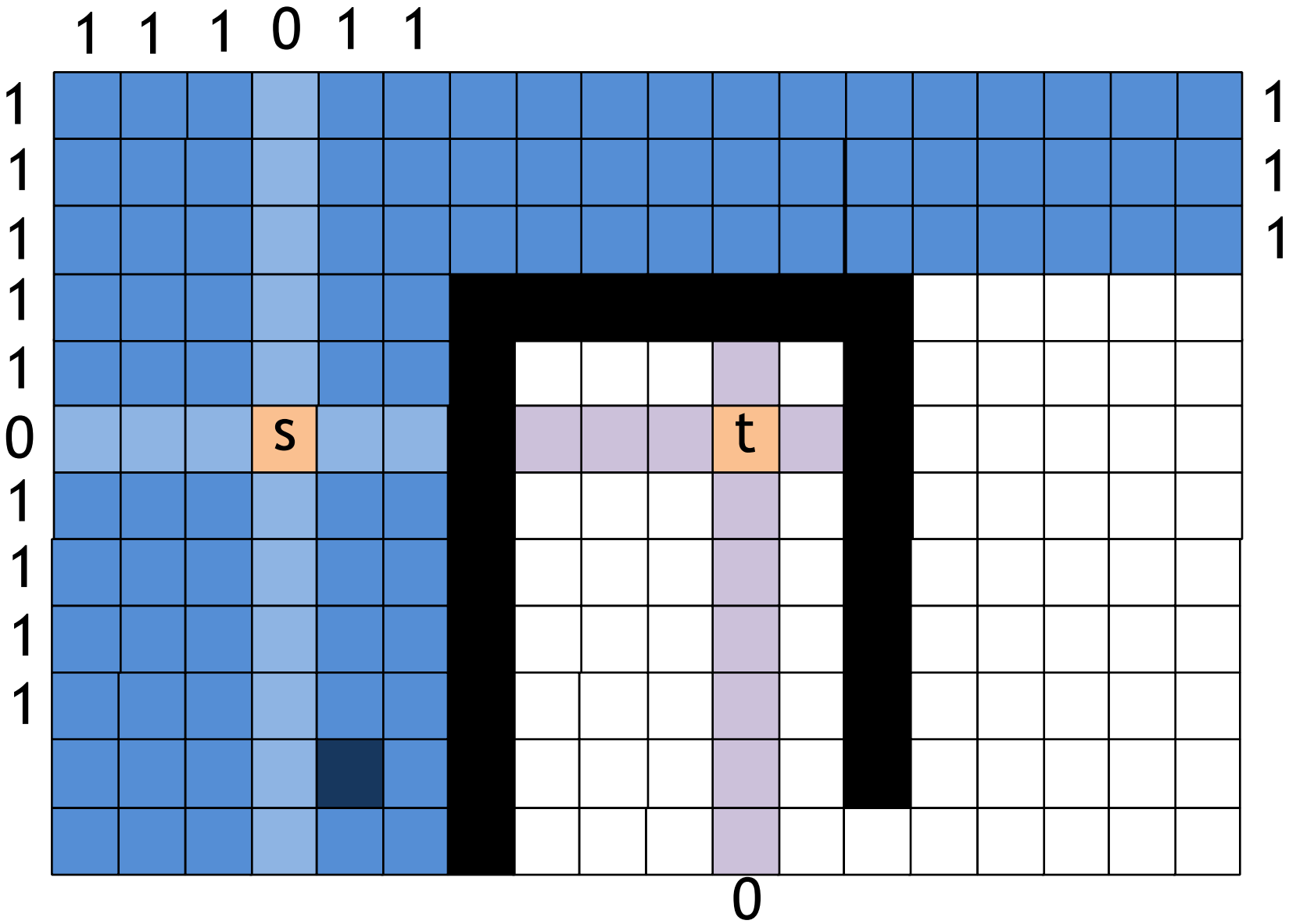
Source Line Probe (Level 1)



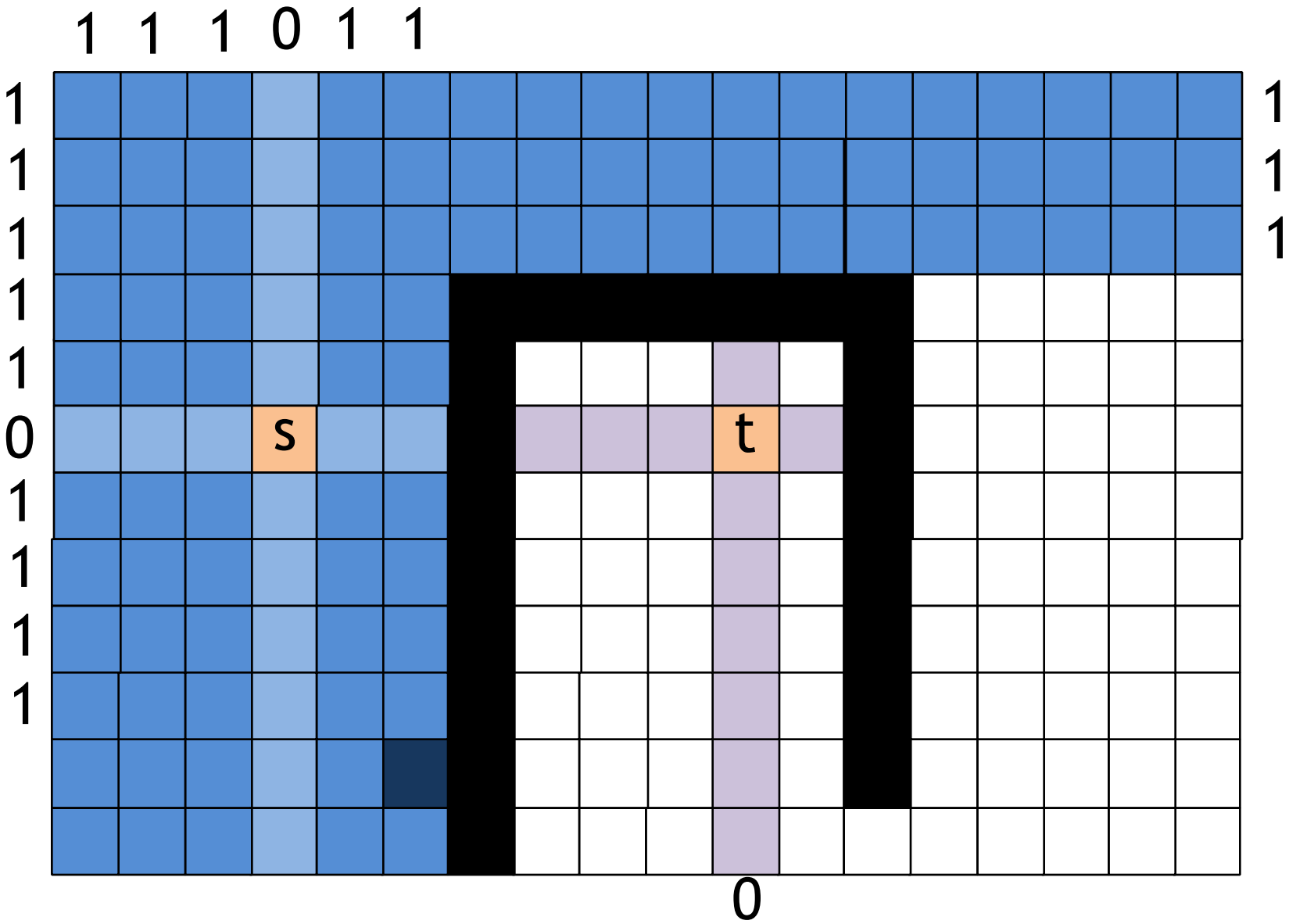
Source Line Probe (Level 1)



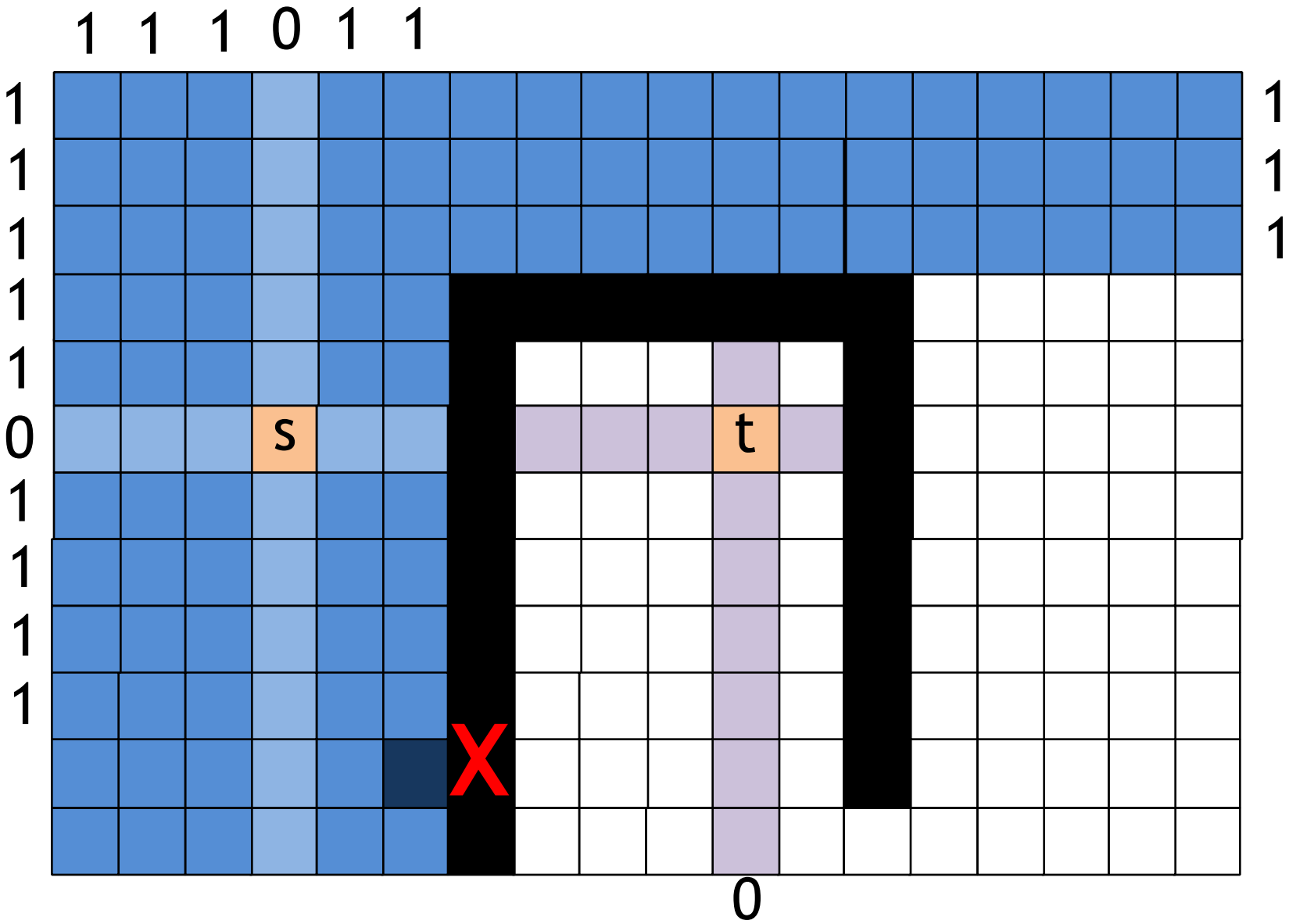
Source Line Probe (Level 1)



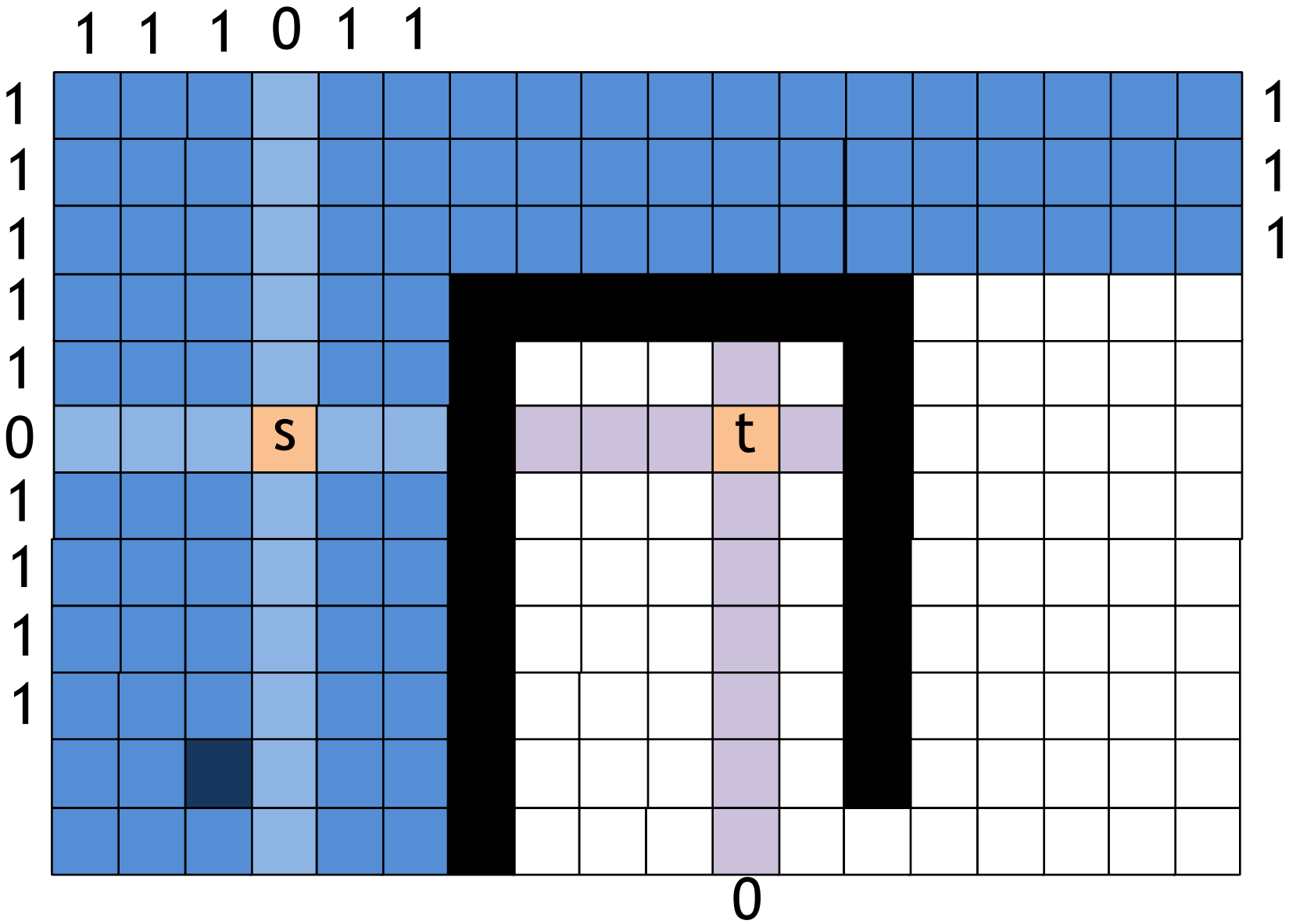
Source Line Probe (Level 1)



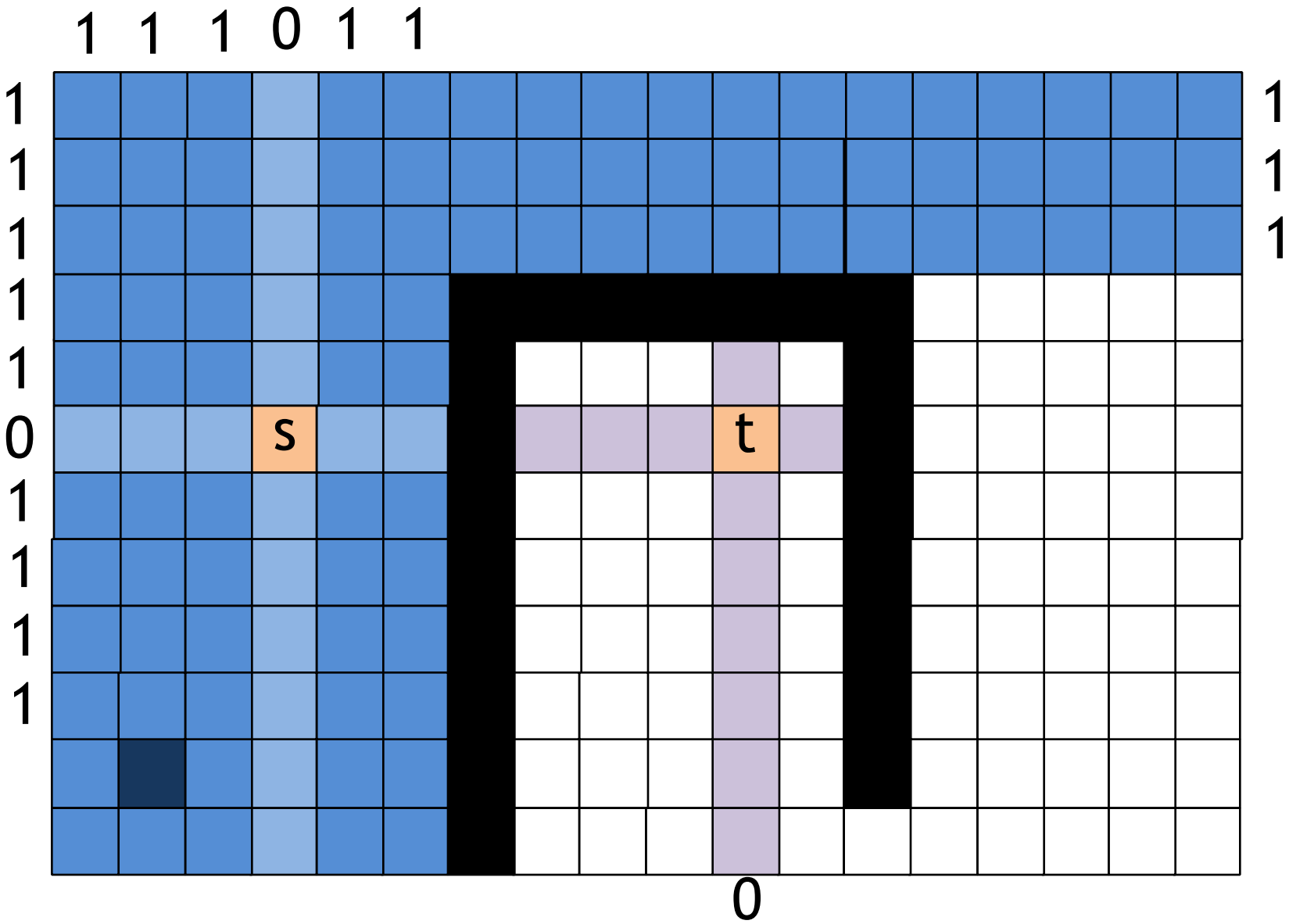
Source Line Probe (Level 1)



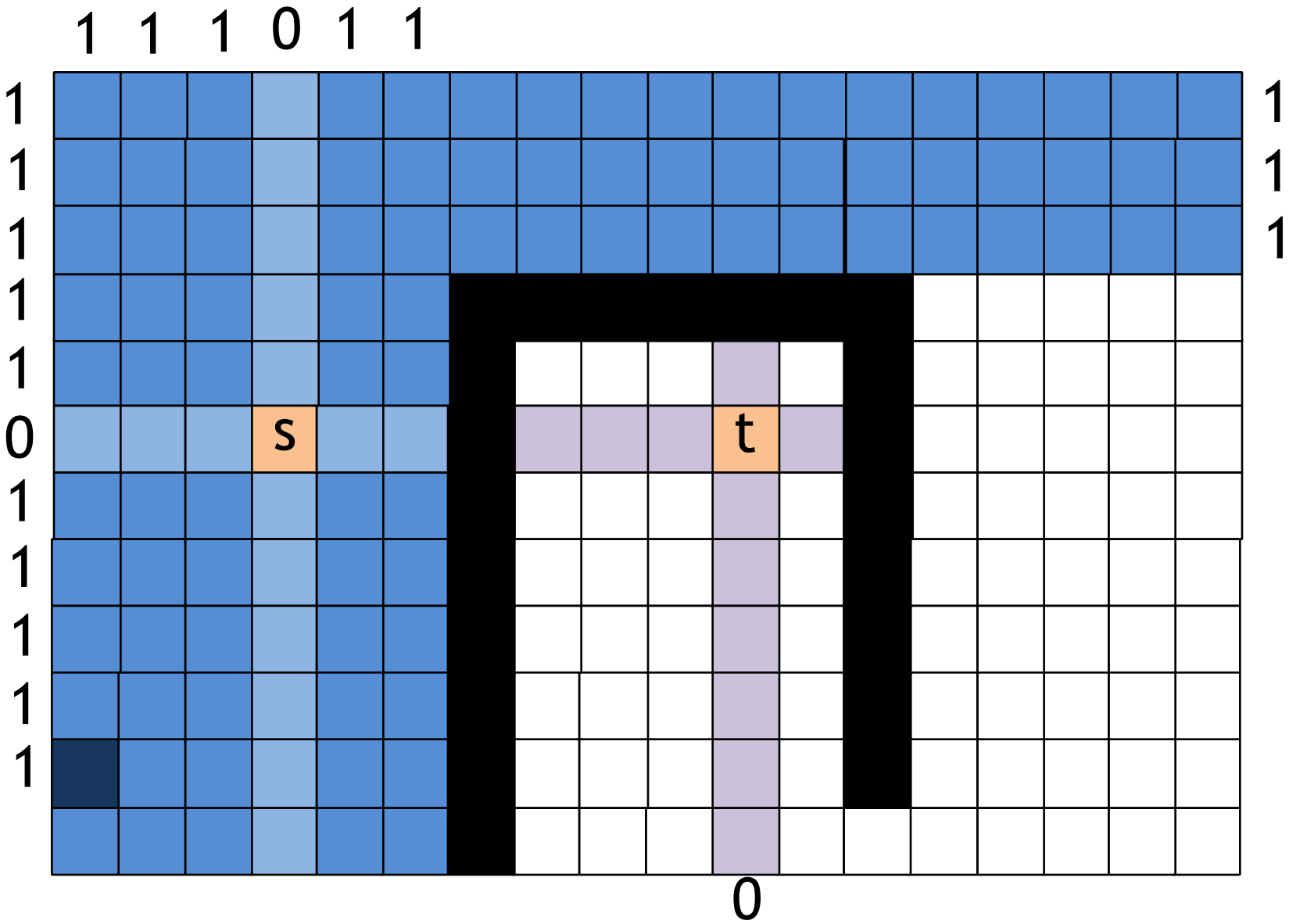
Source Line Probe (Level 1)



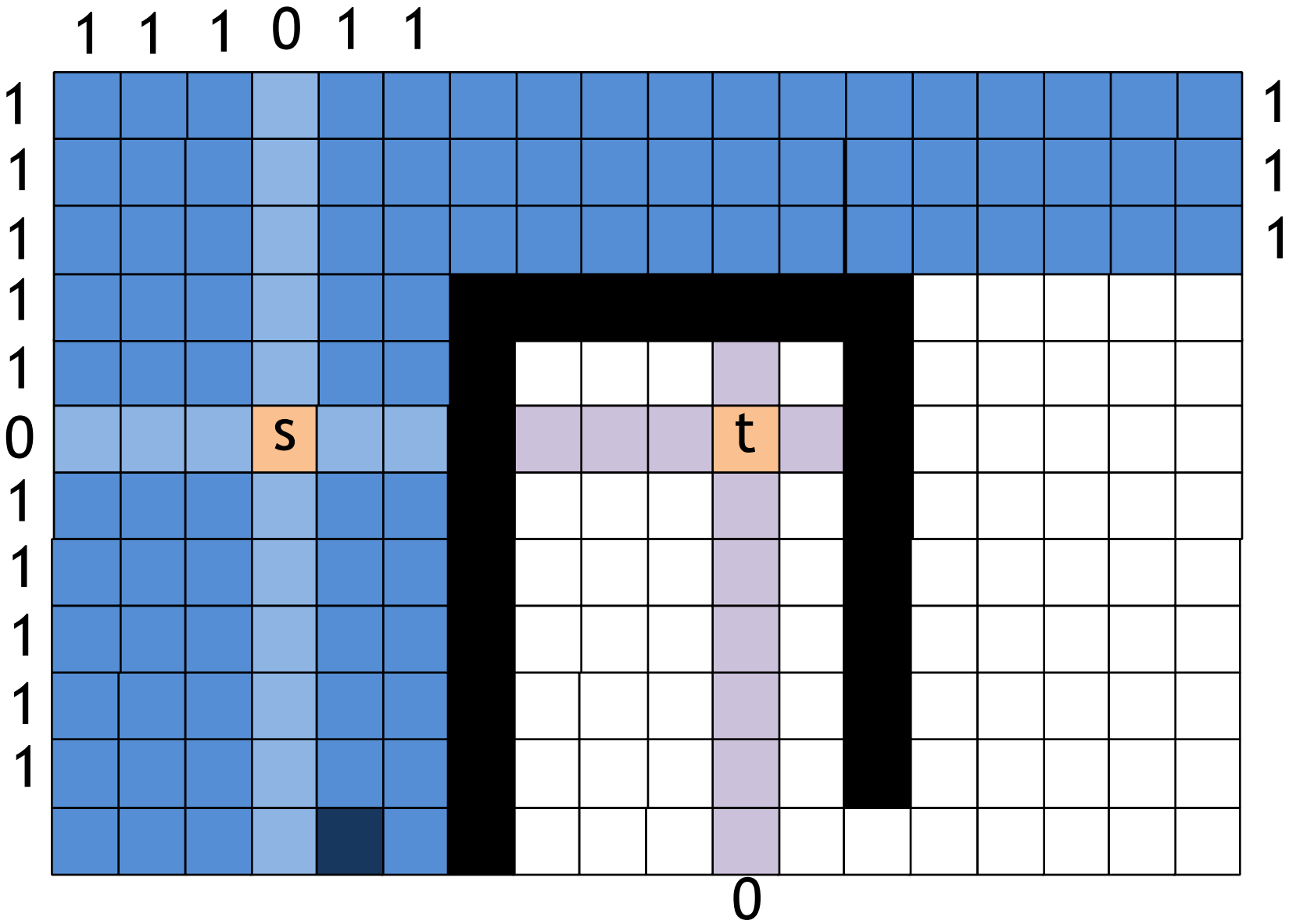
Source Line Probe (Level 1)



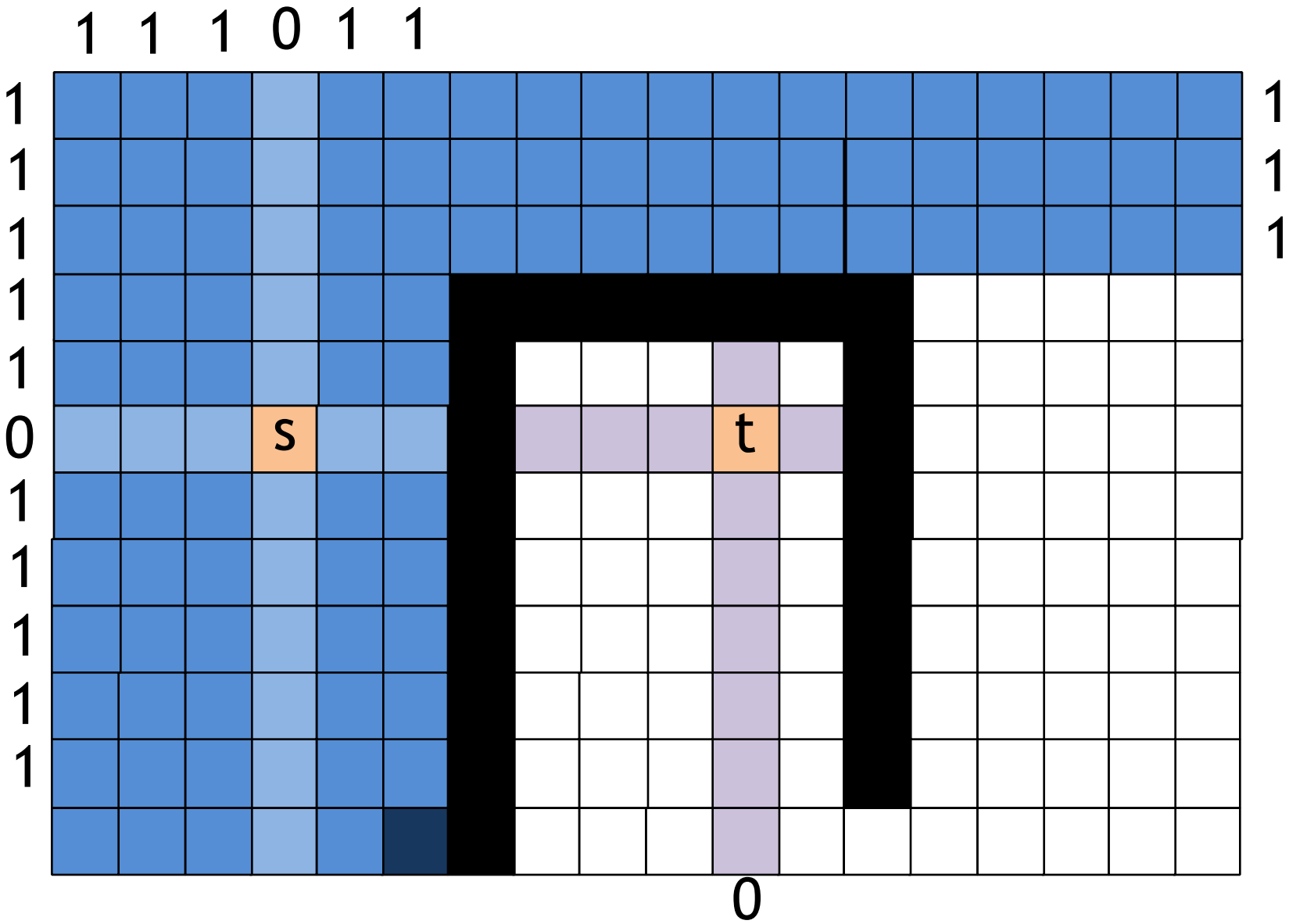
Source Line Probe (Level 1)



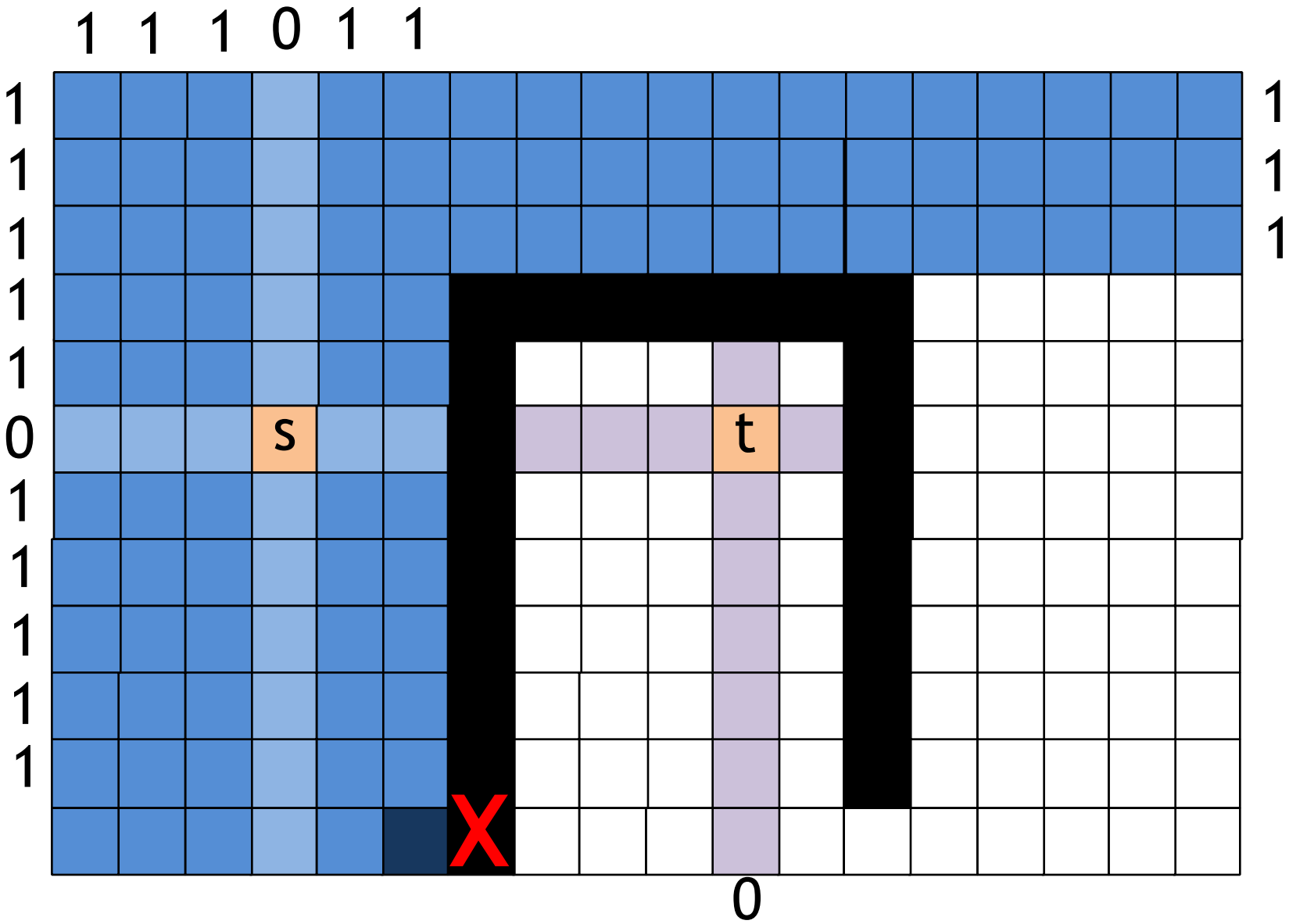
Source Line Probe (Level 1)



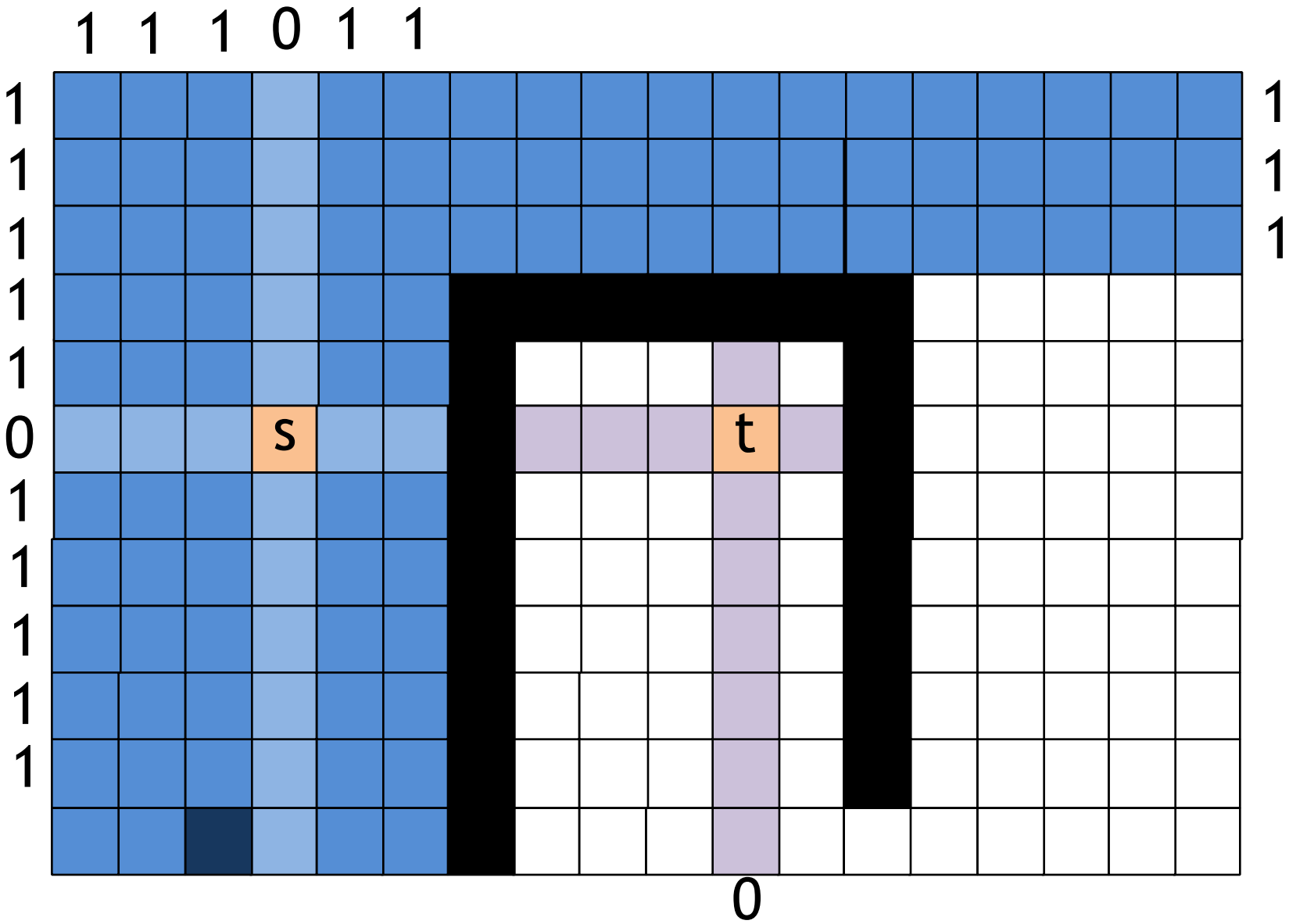
Source Line Probe (Level 1)



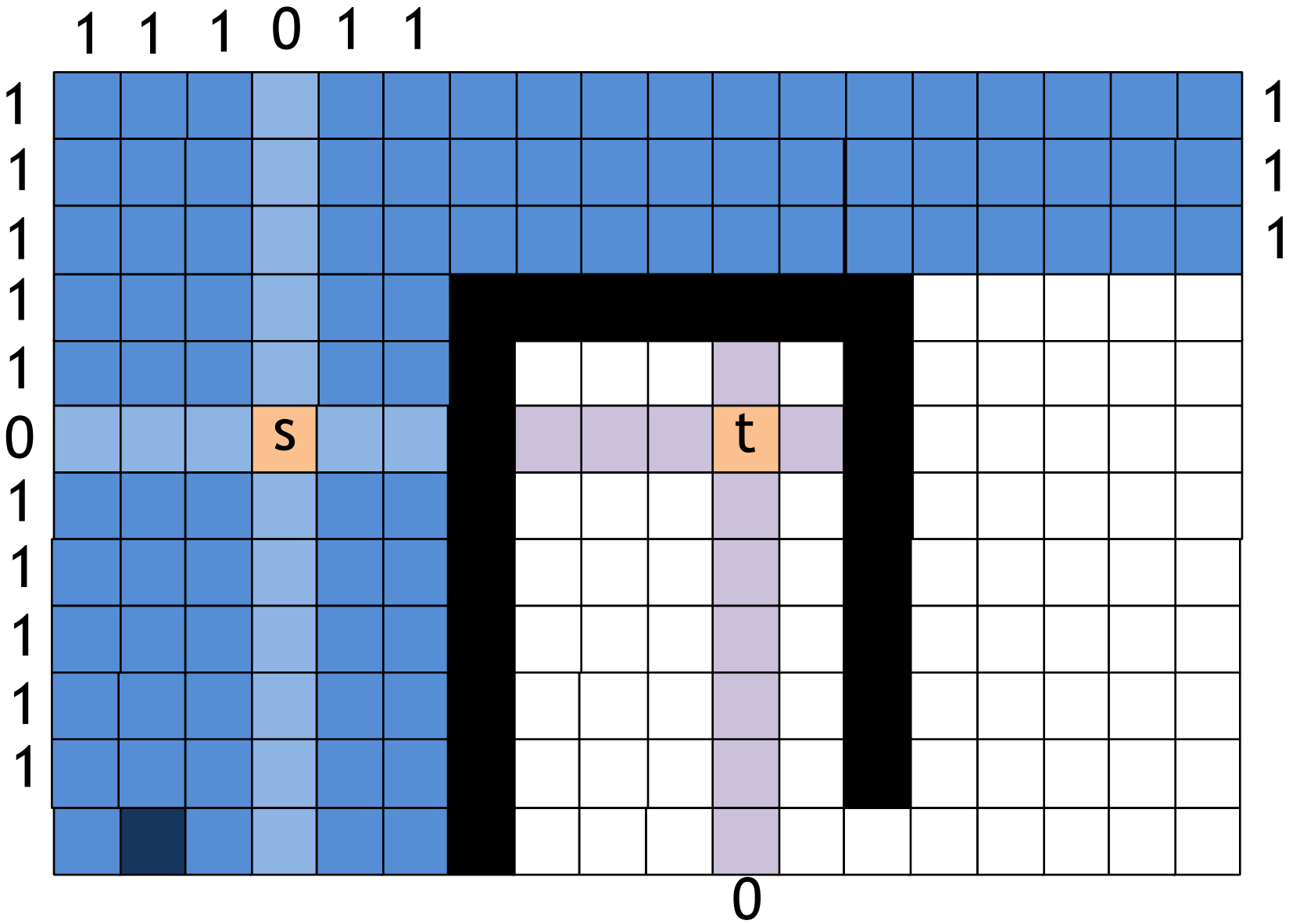
Source Line Probe (Level 1)



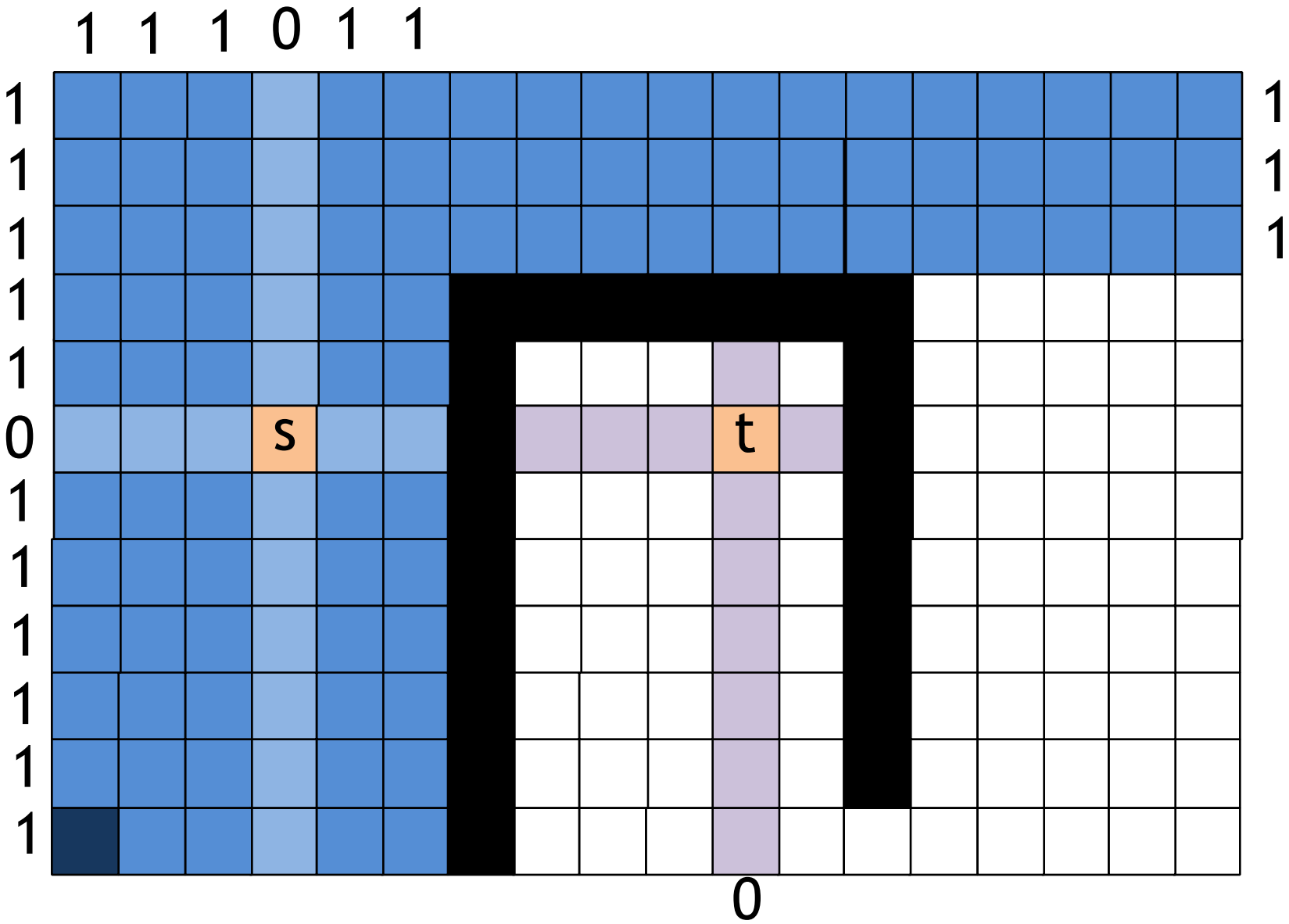
Source Line Probe (Level 1)



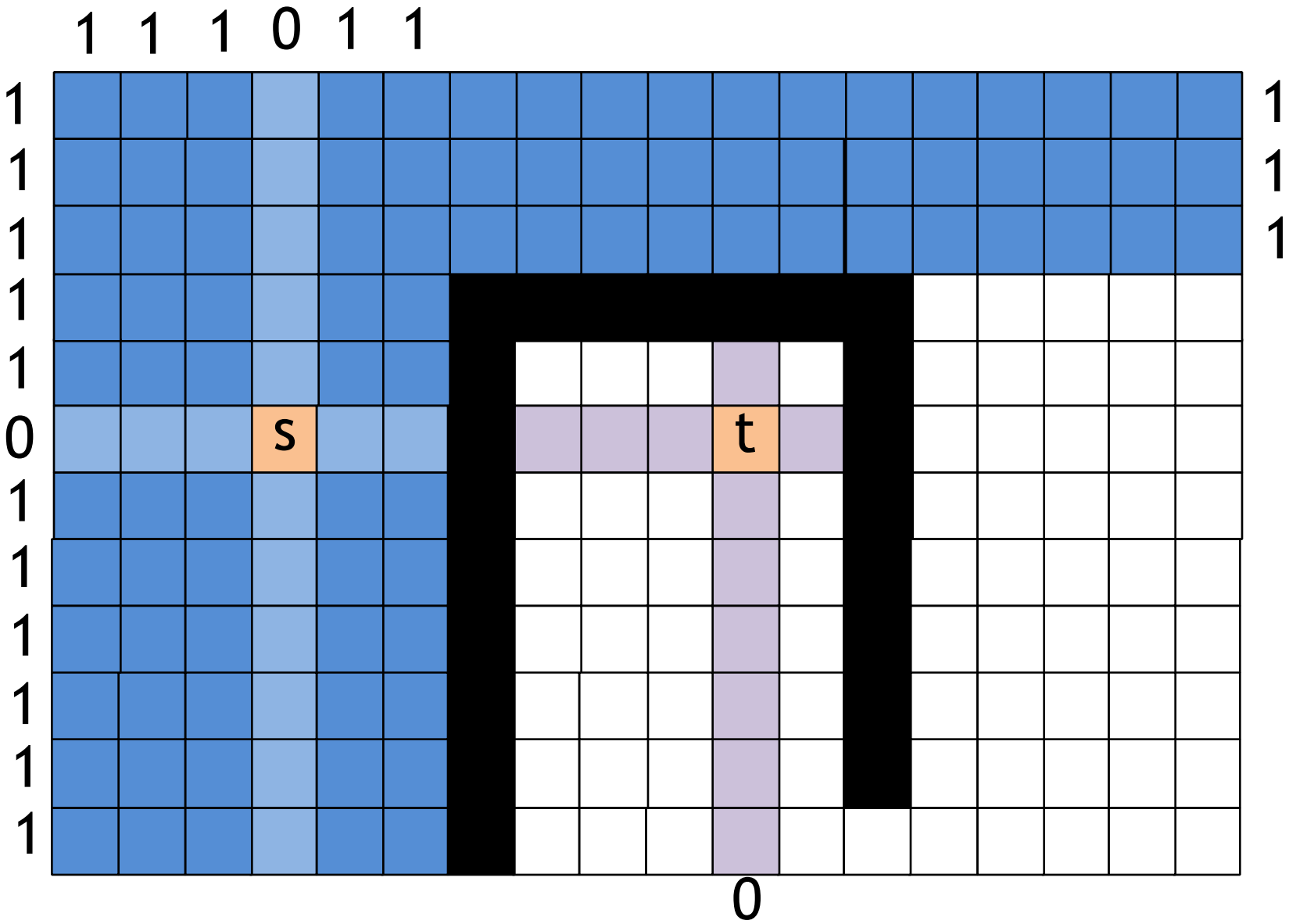
Source Line Probe (Level 1)



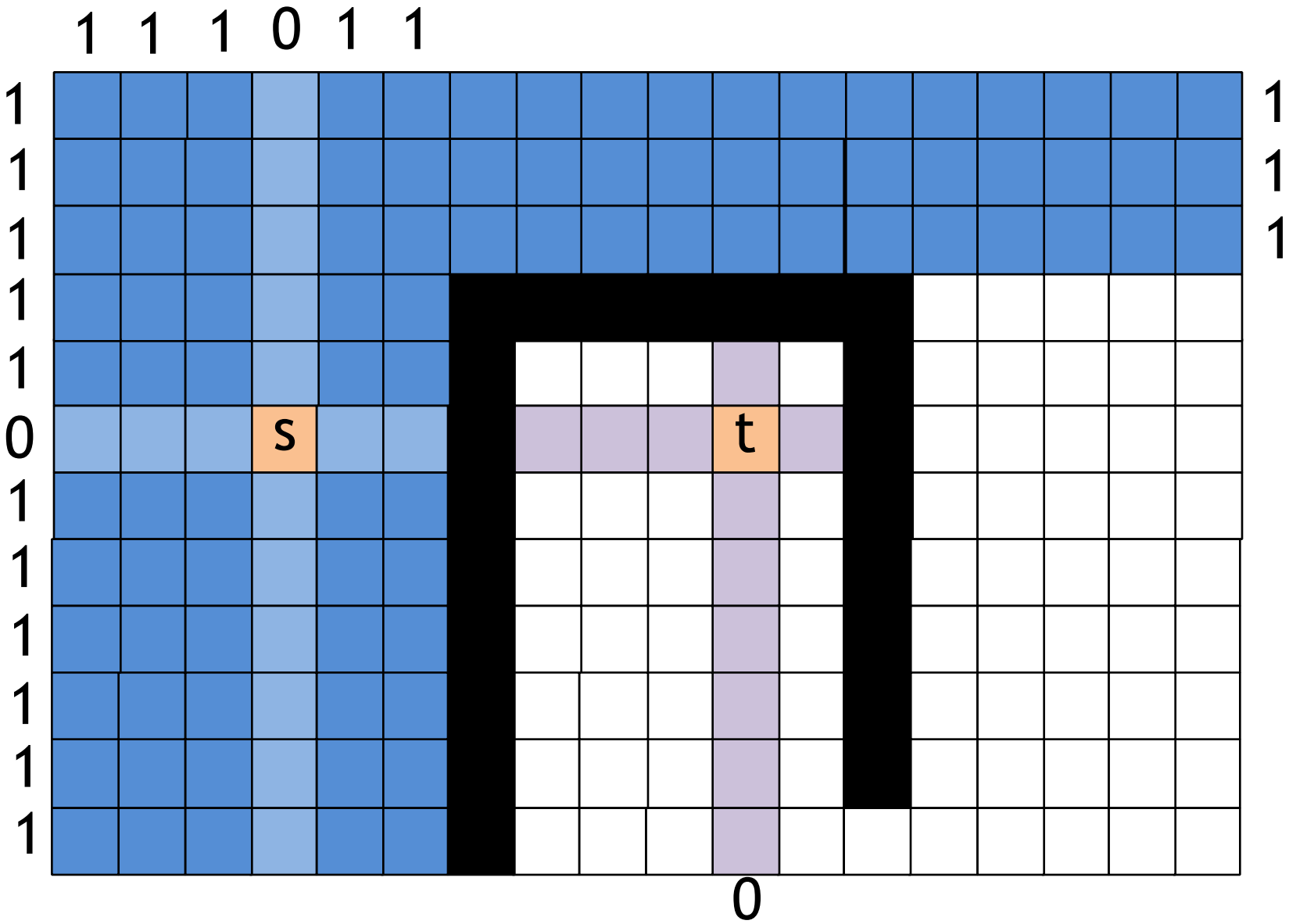
Source Line Probe (Level 1)



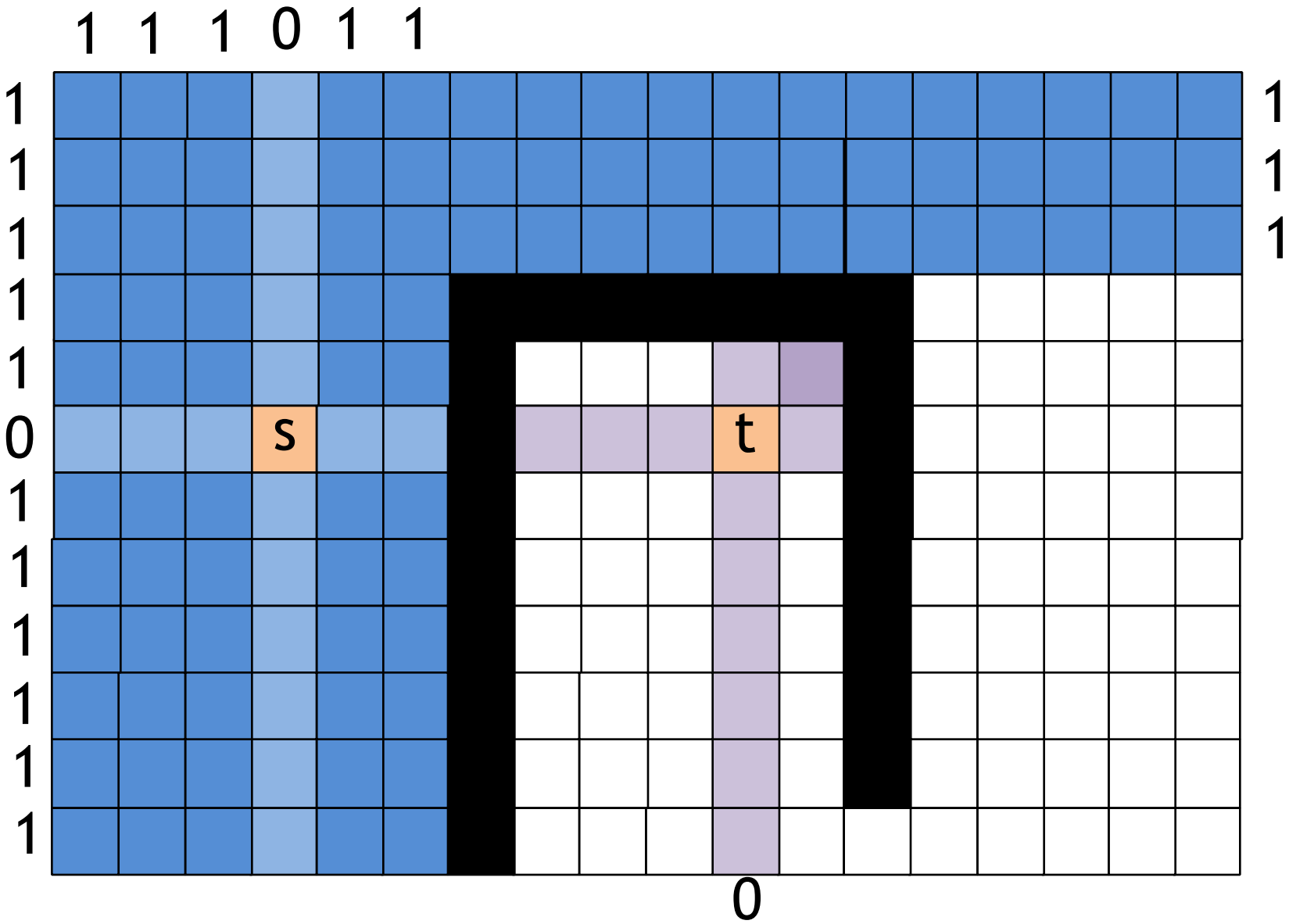
And Now… to the Sink!



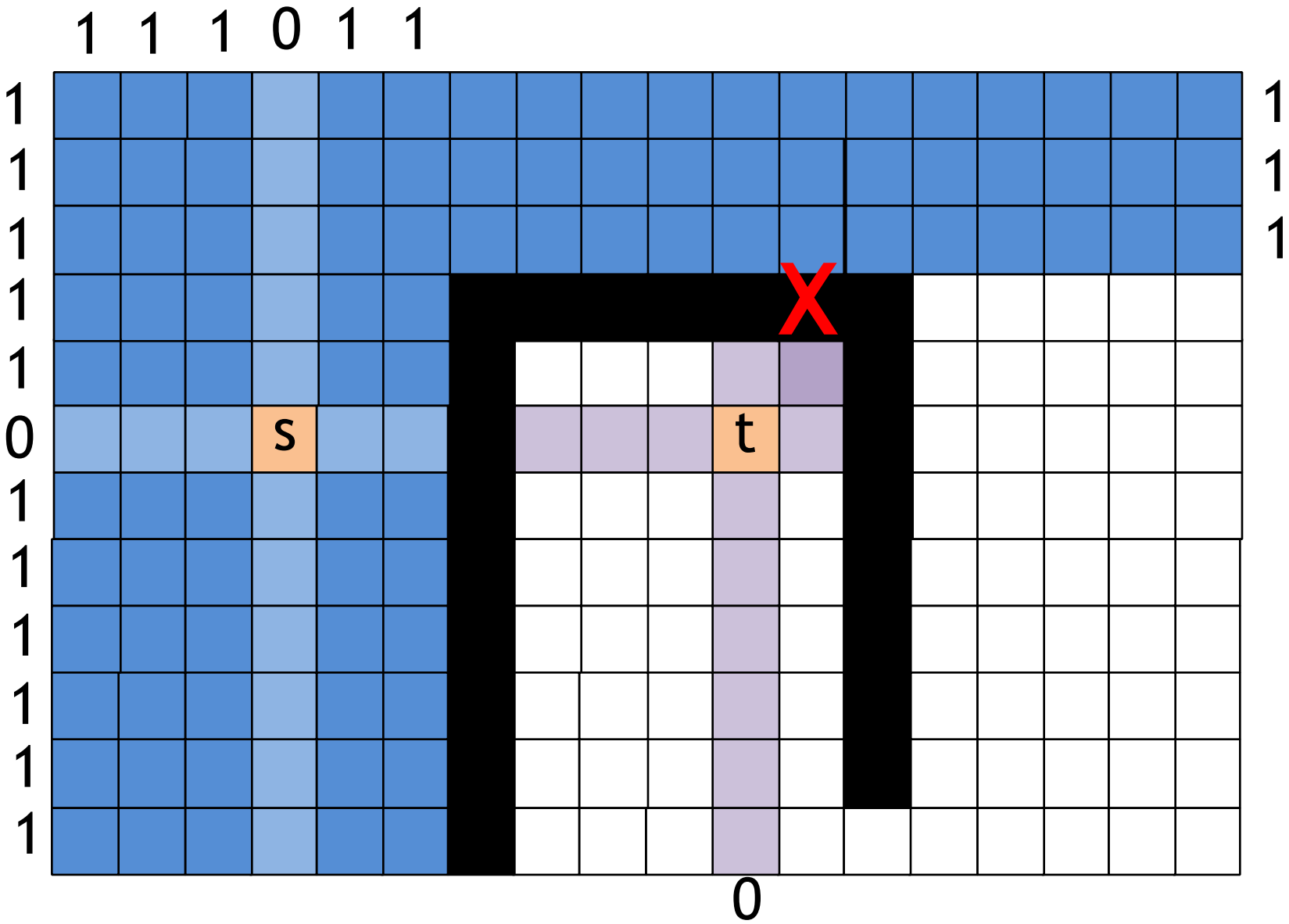
Sink Line Probe (Level 1)



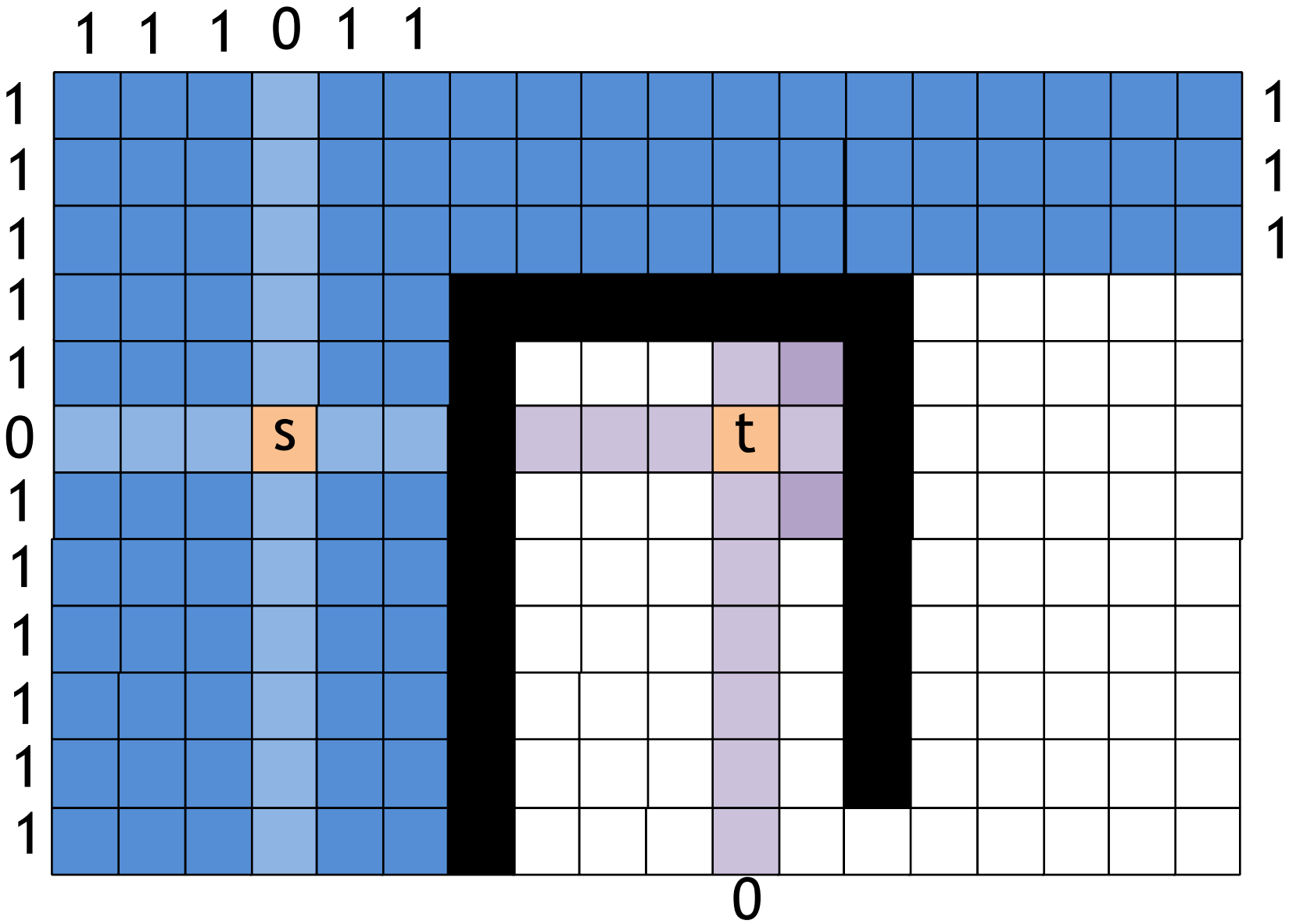
Sink Line Probe (Level 1)



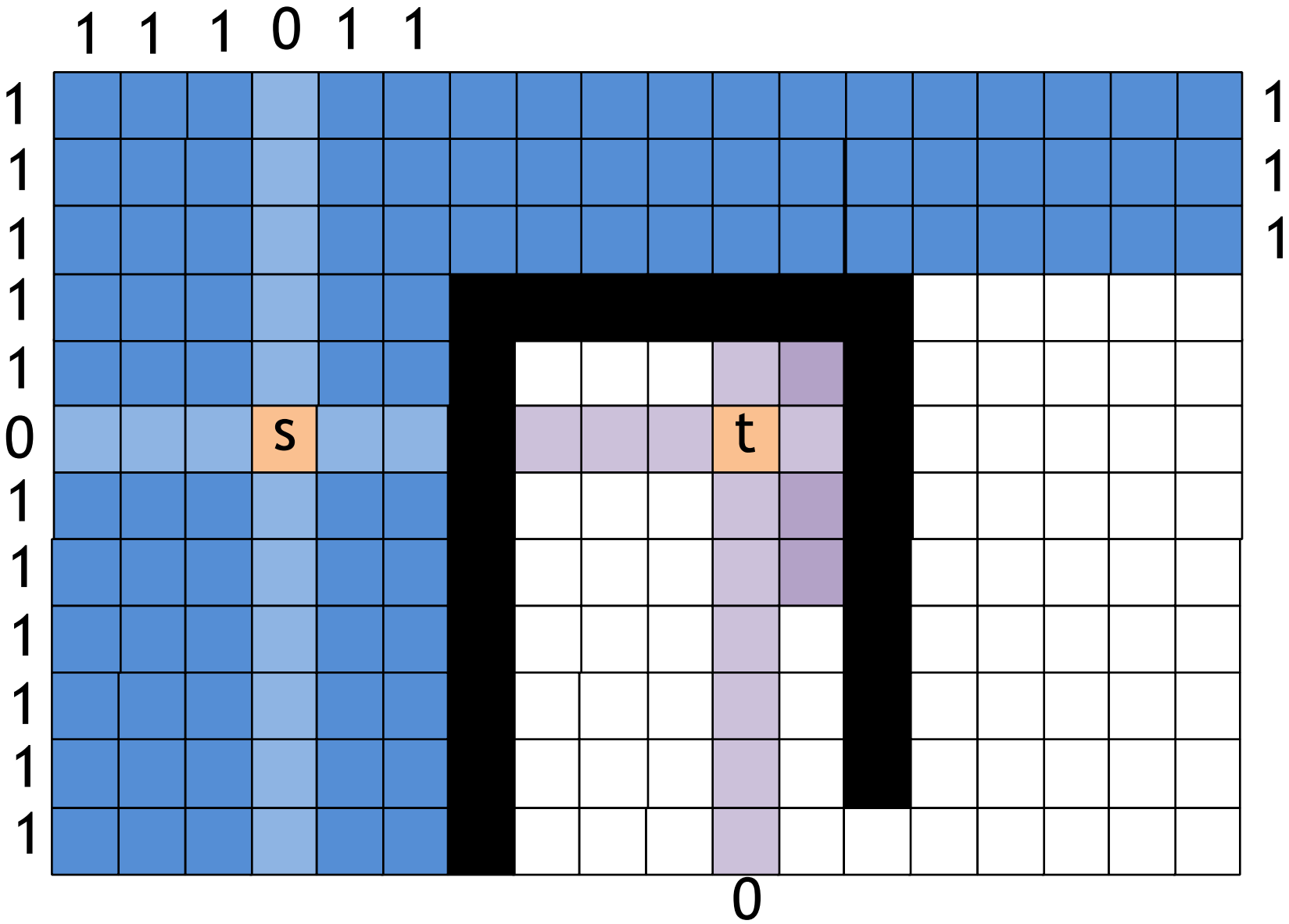
Sink Line Probe (Level 1)



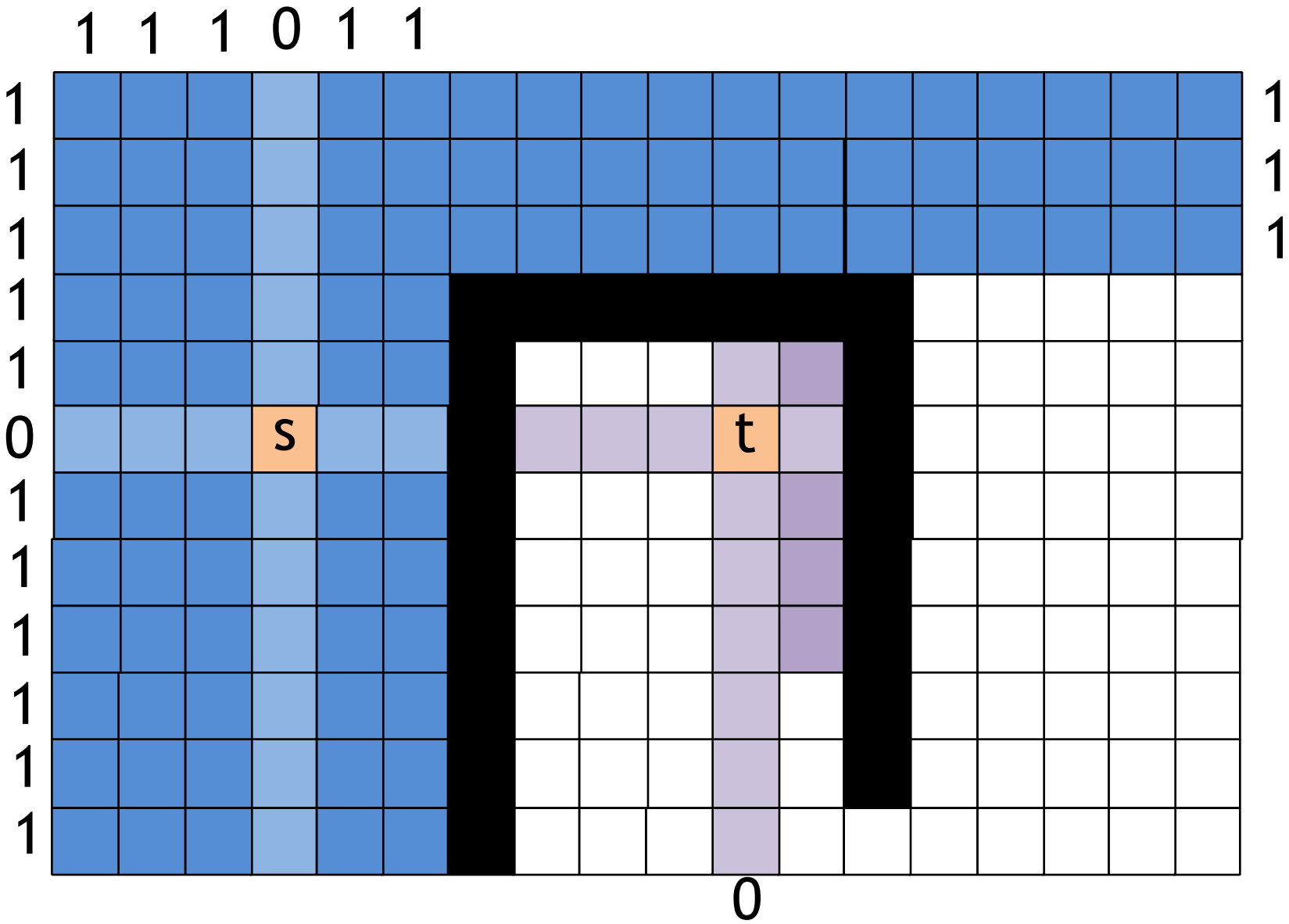
Sink Line Probe (Level 1)



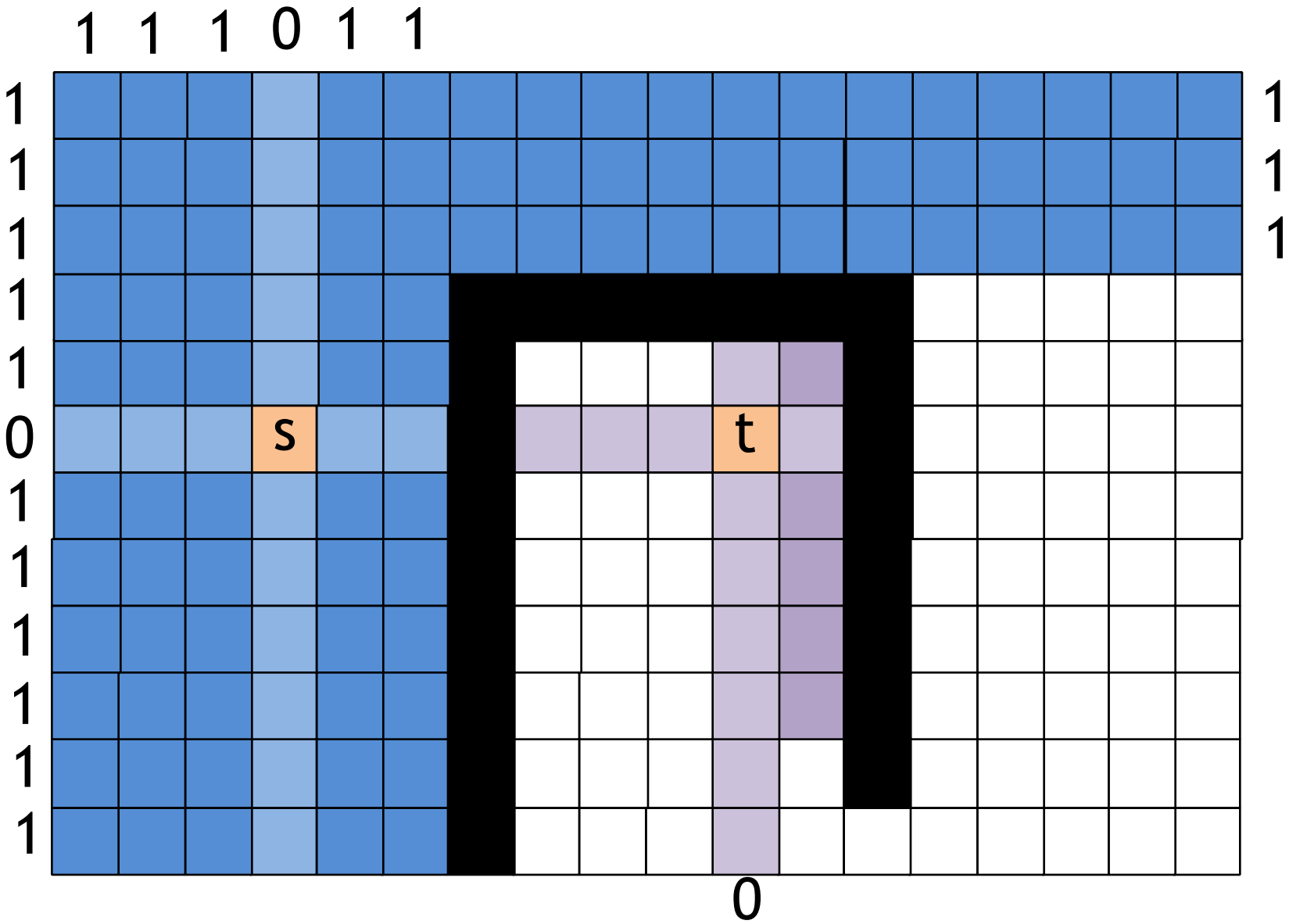
Sink Line Probe (Level 1)



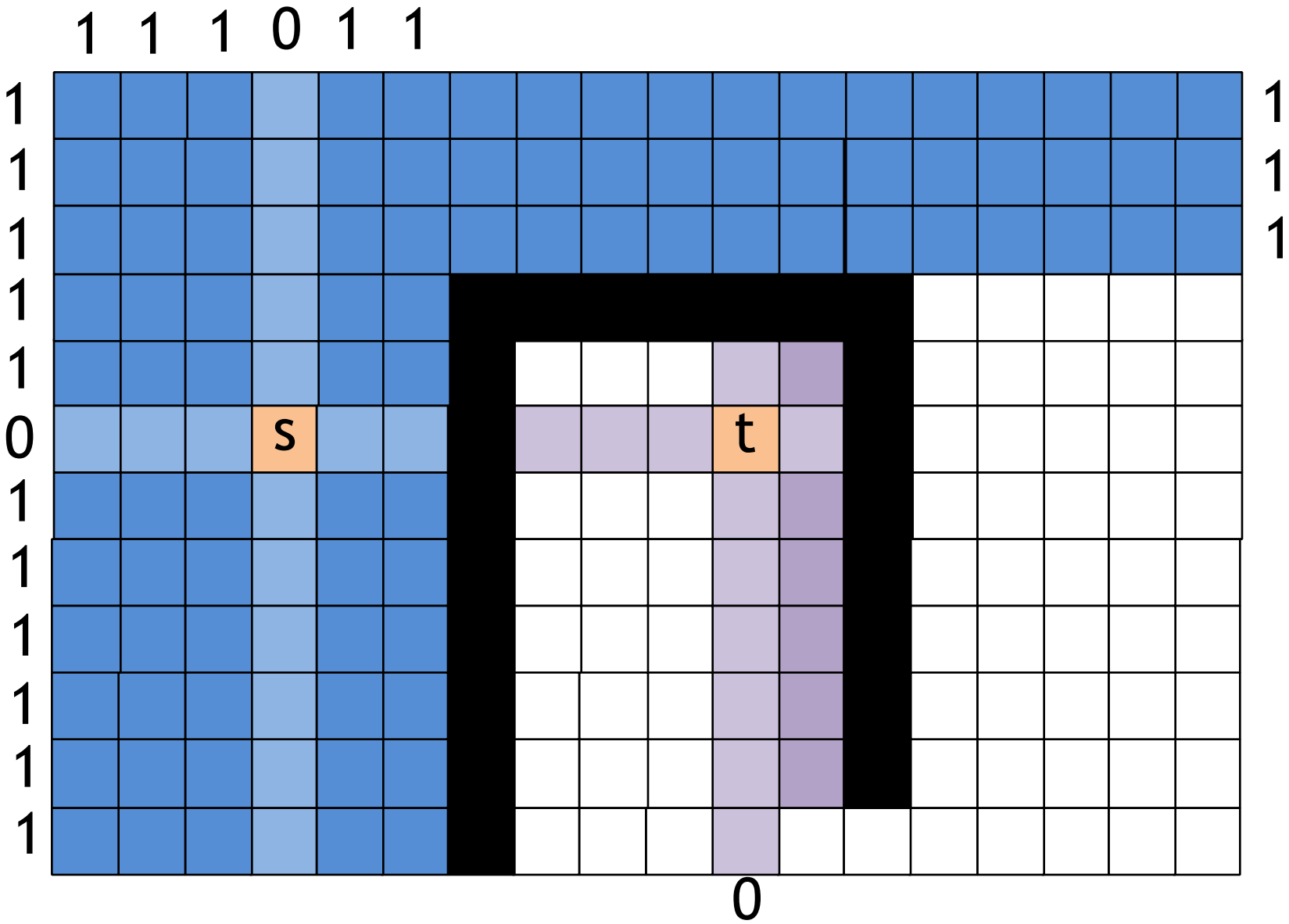
Sink Line Probe (Level 1)



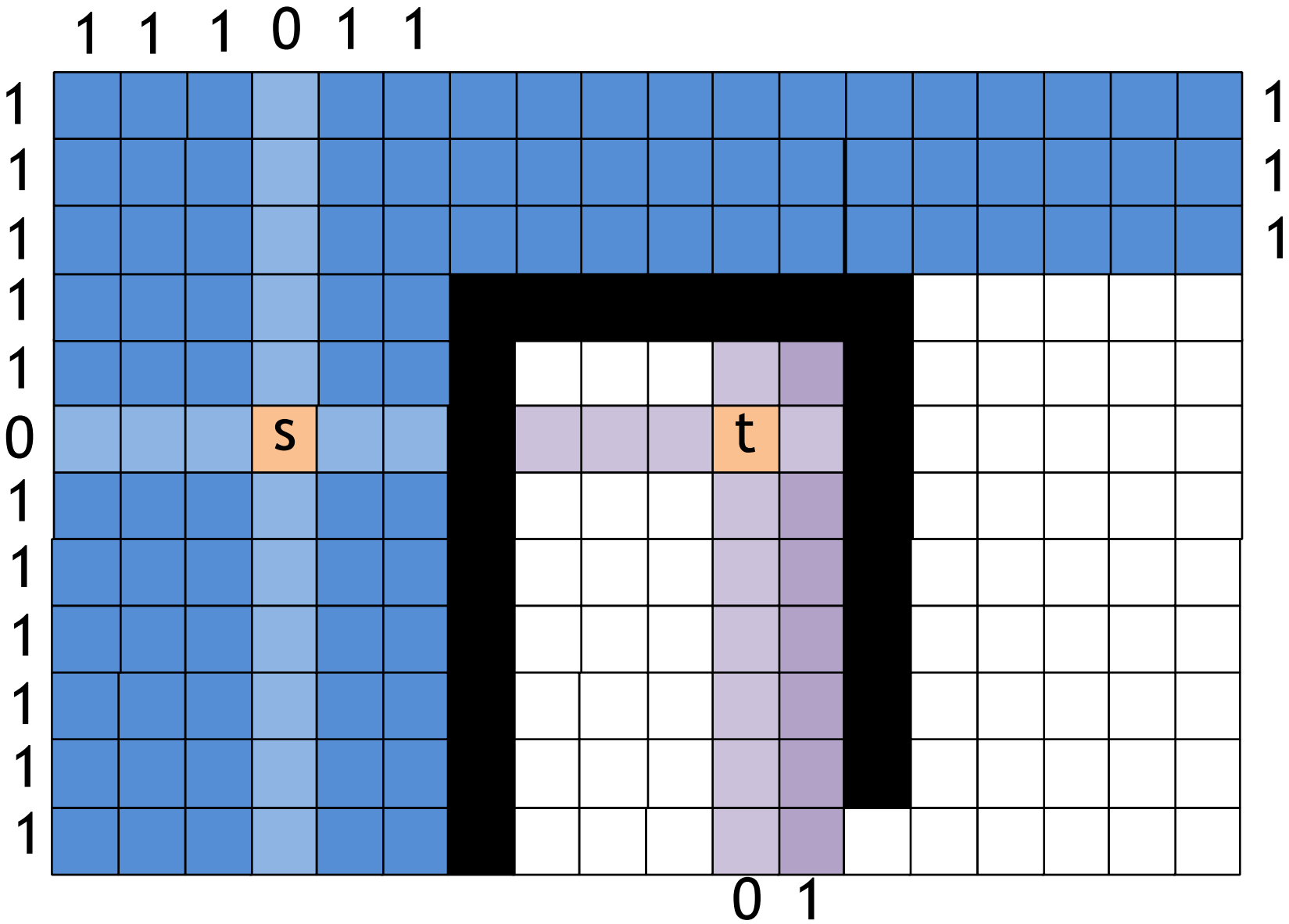
Sink Line Probe (Level 1)



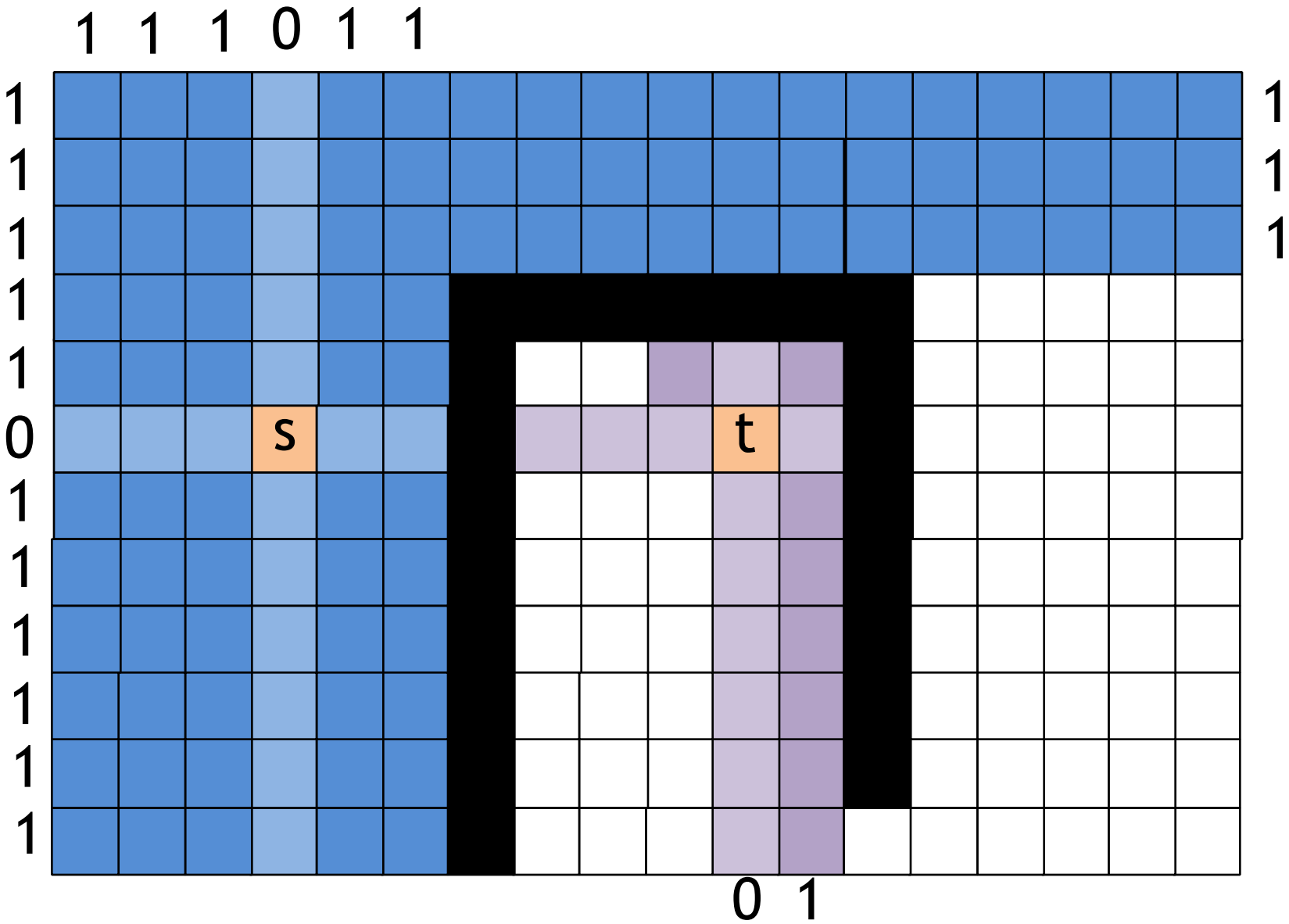
Sink Line Probe (Level 1)



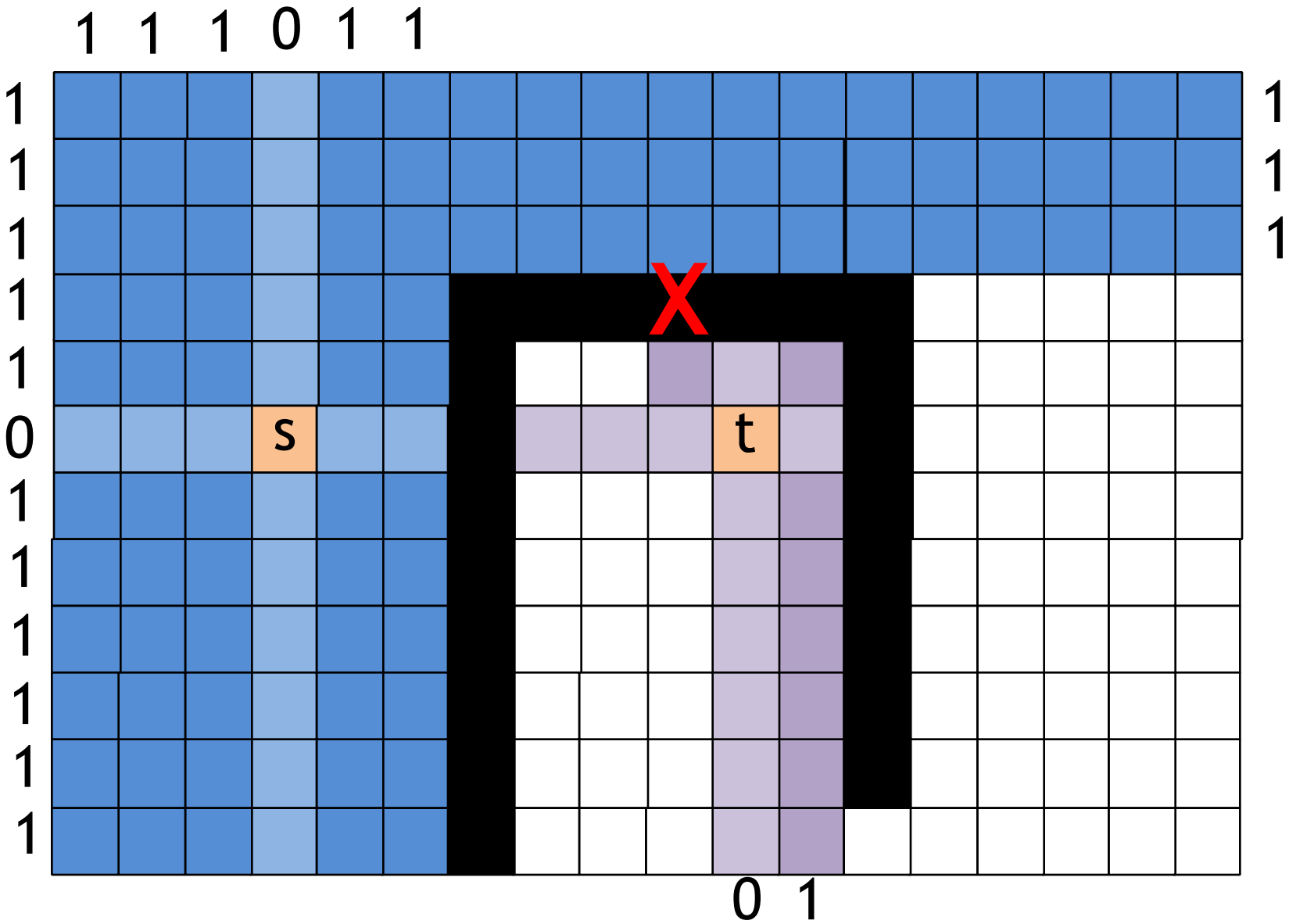
Sink Line Probe (Level 1)



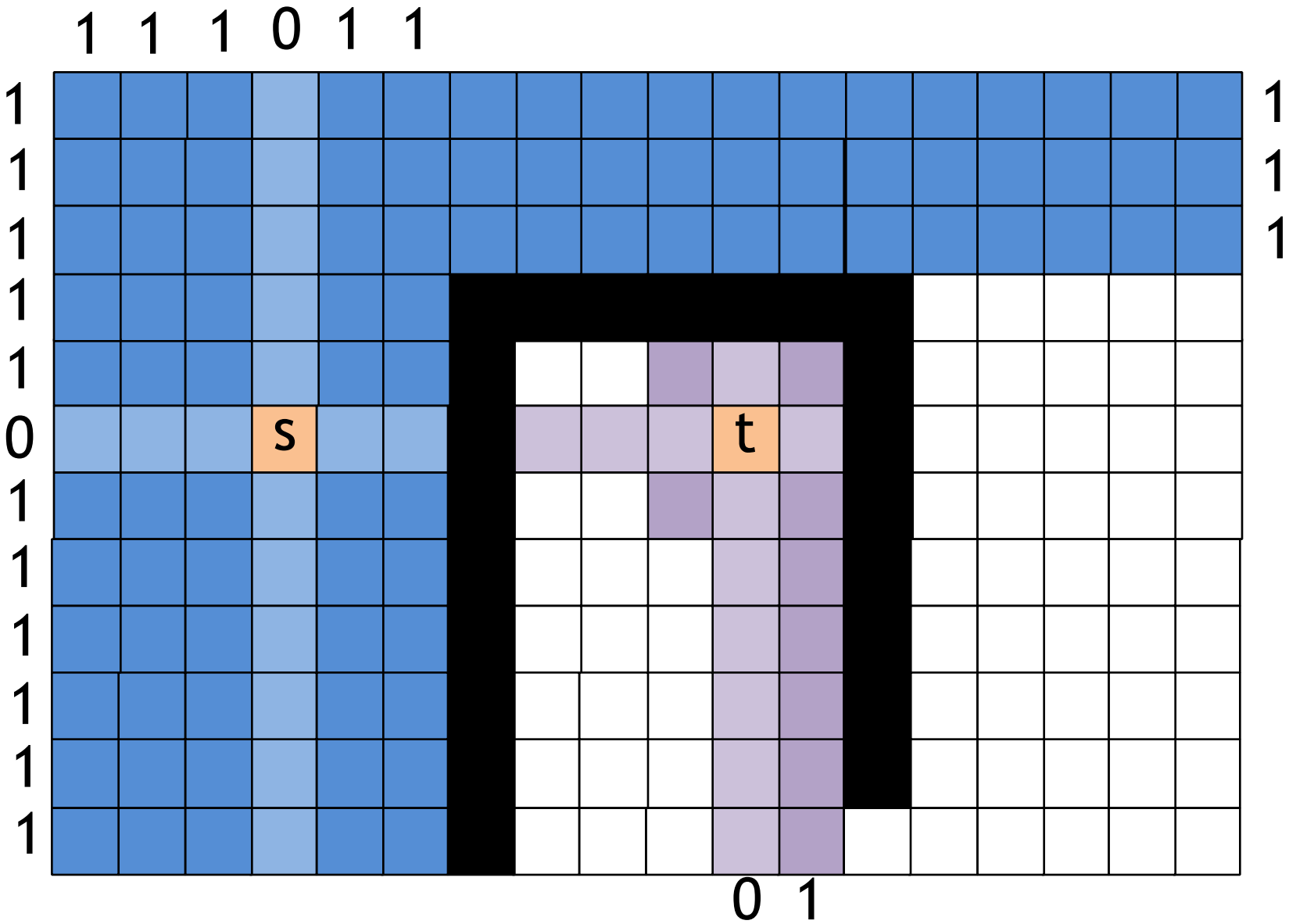
Sink Line Probe (Level 1)



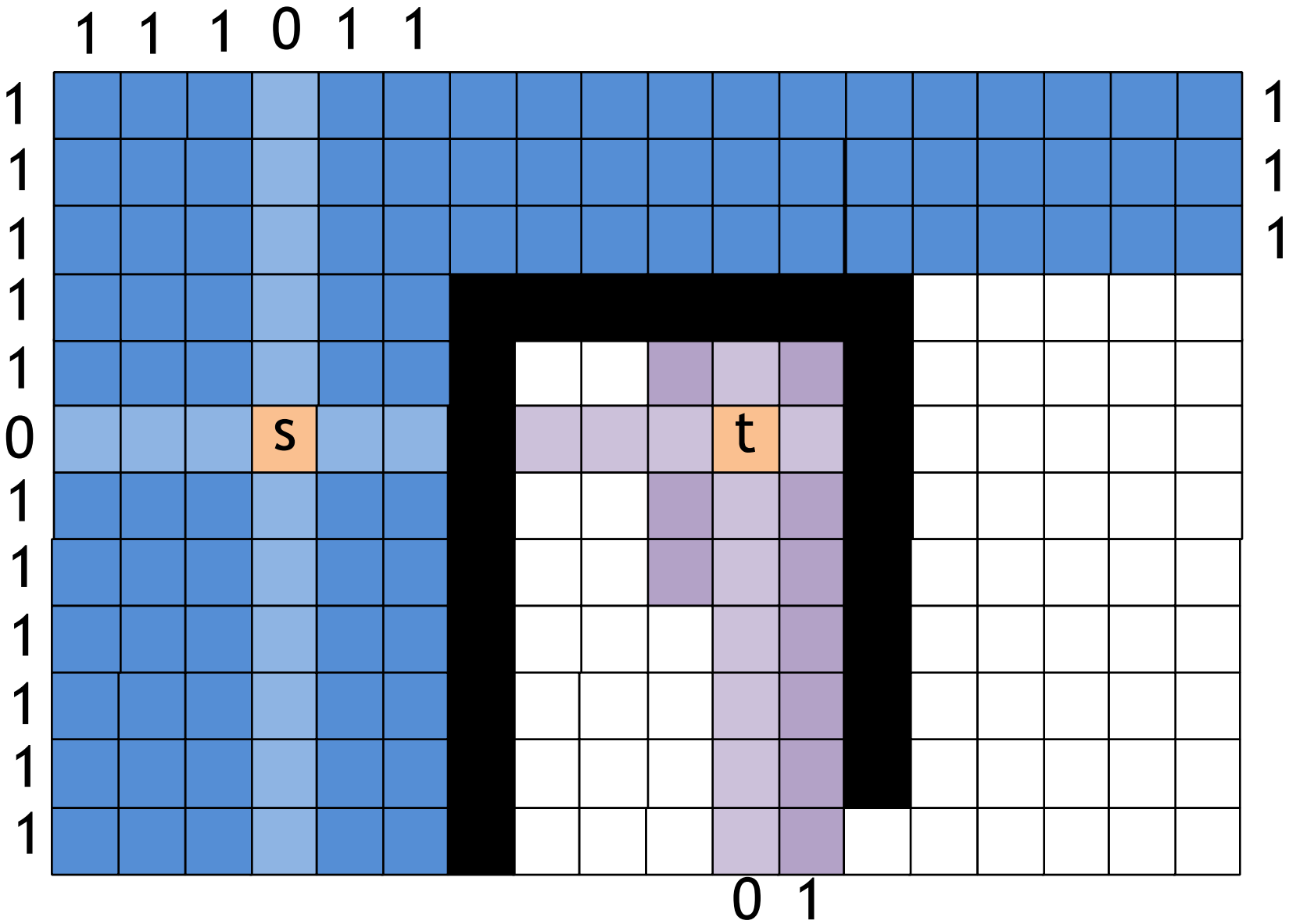
Sink Line Probe (Level 1)



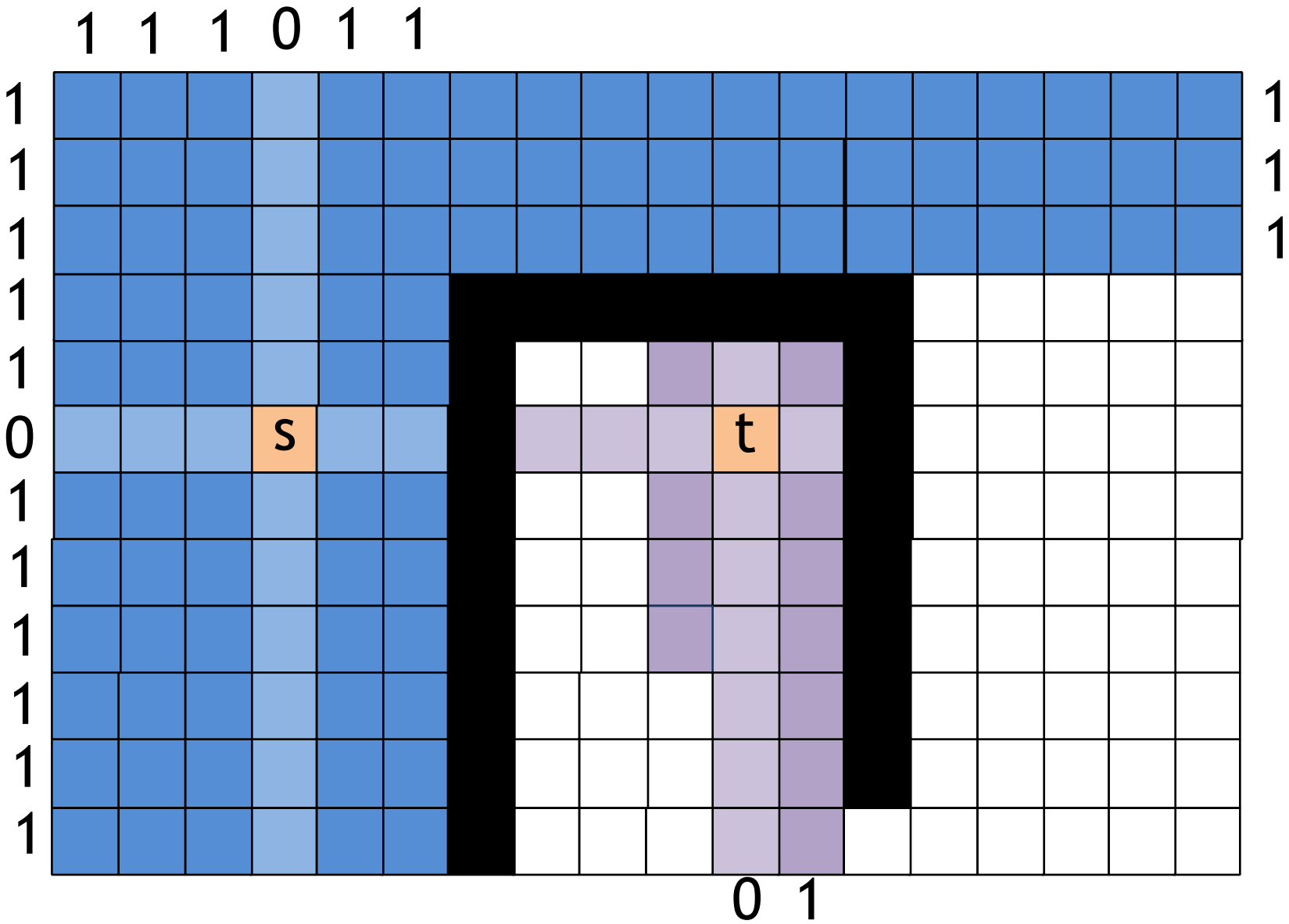
Sink Line Probe (Level 1)



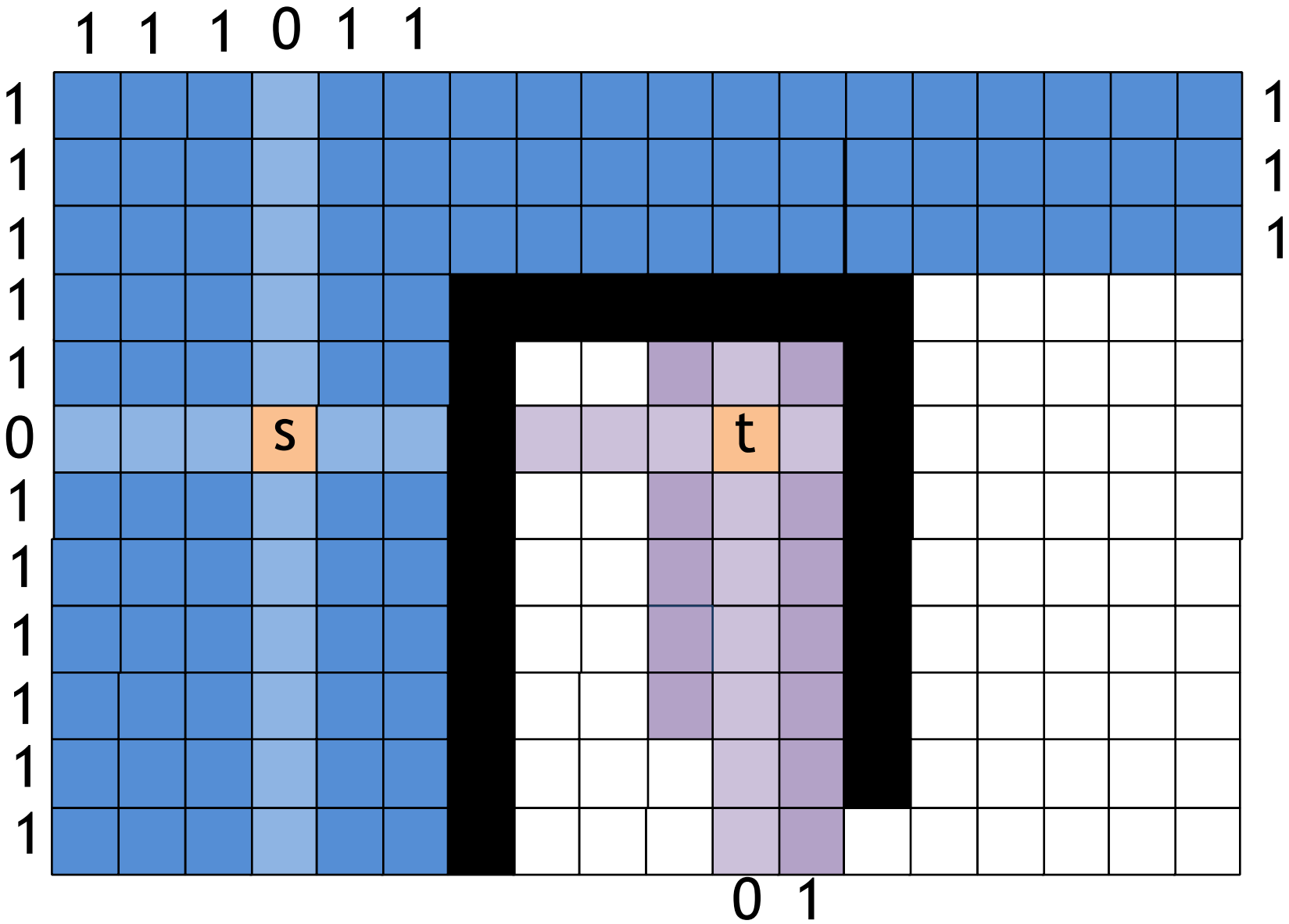
Sink Line Probe (Level 1)



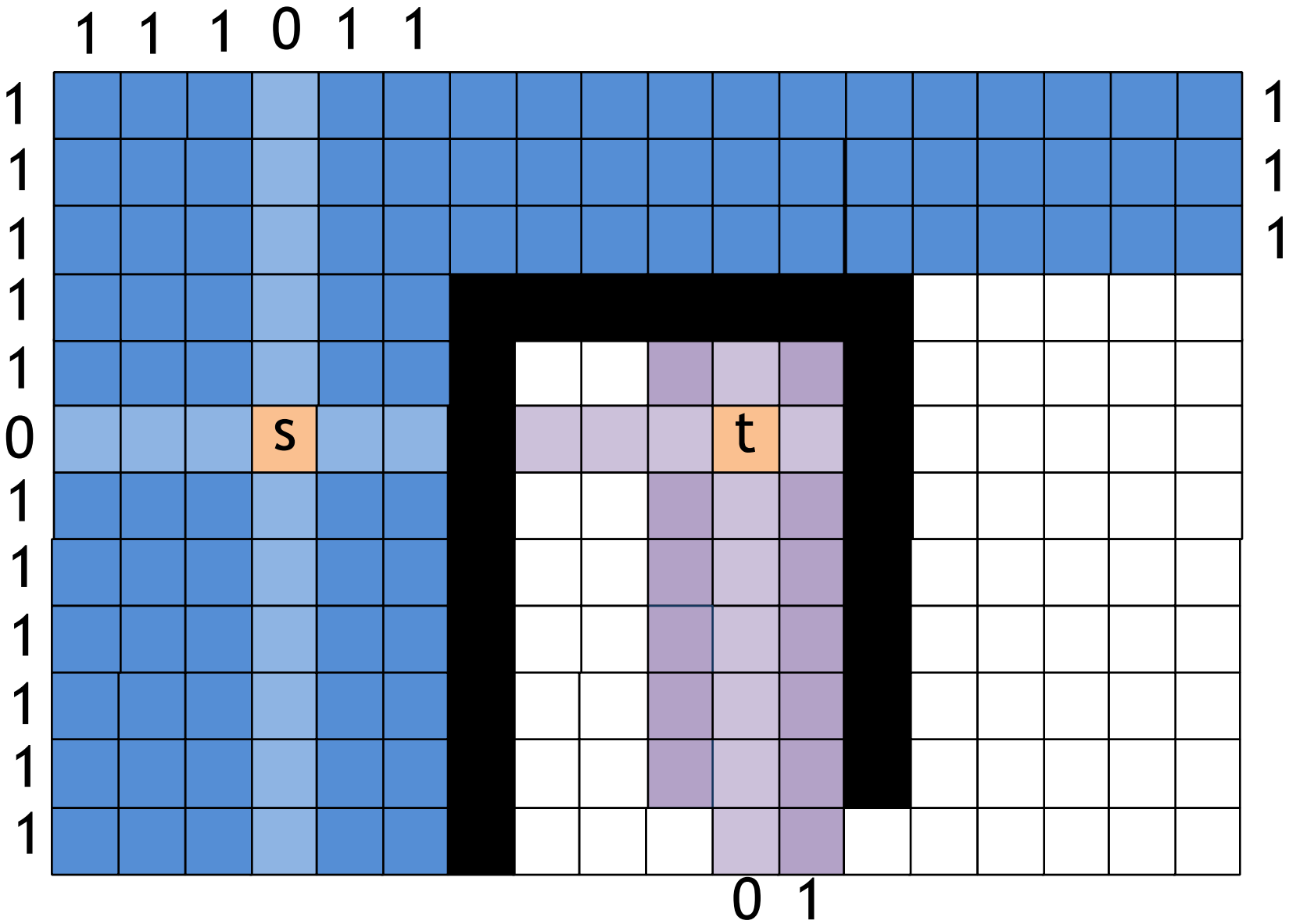
Sink Line Probe (Level 1)



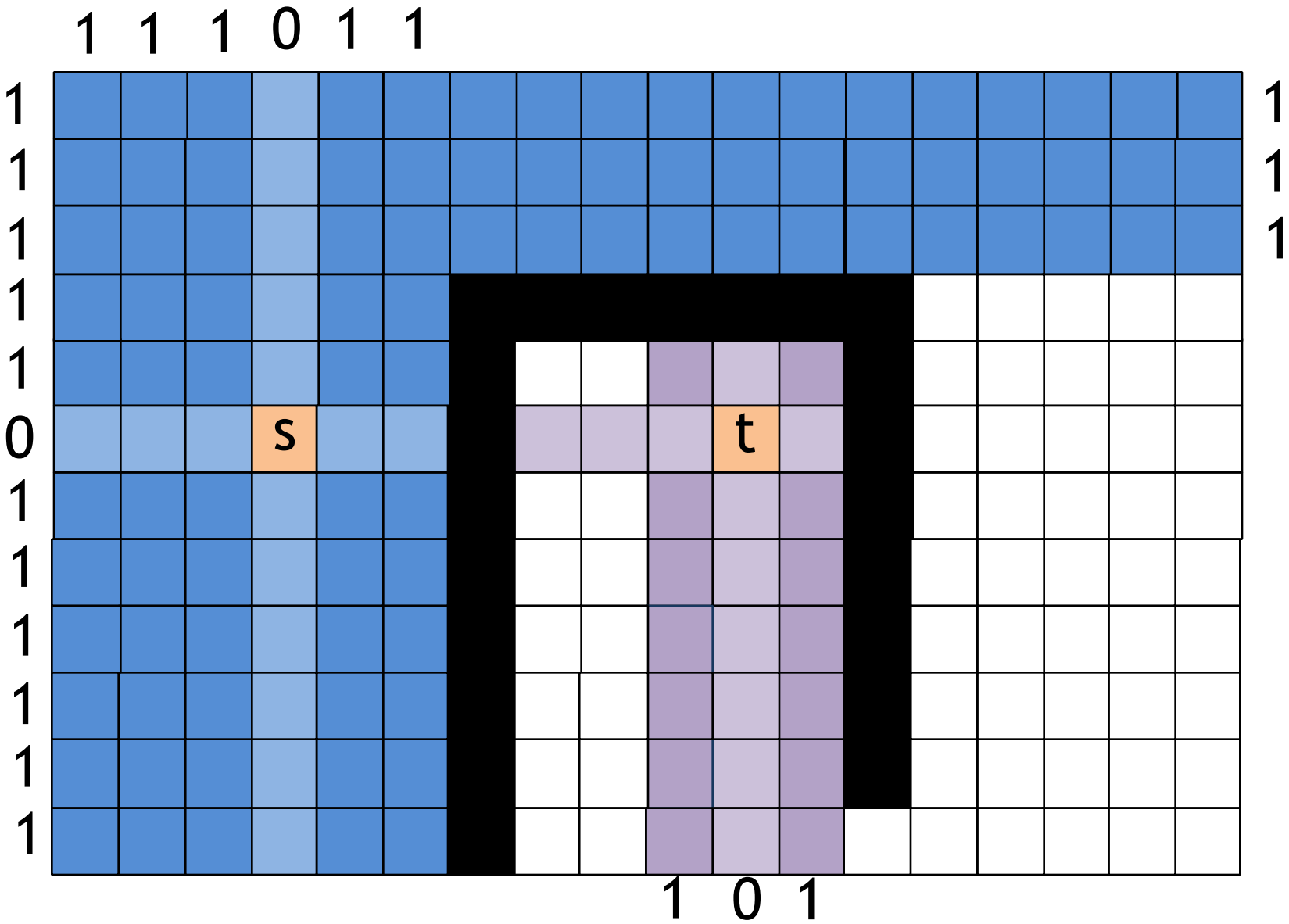
Sink Line Probe (Level 1)



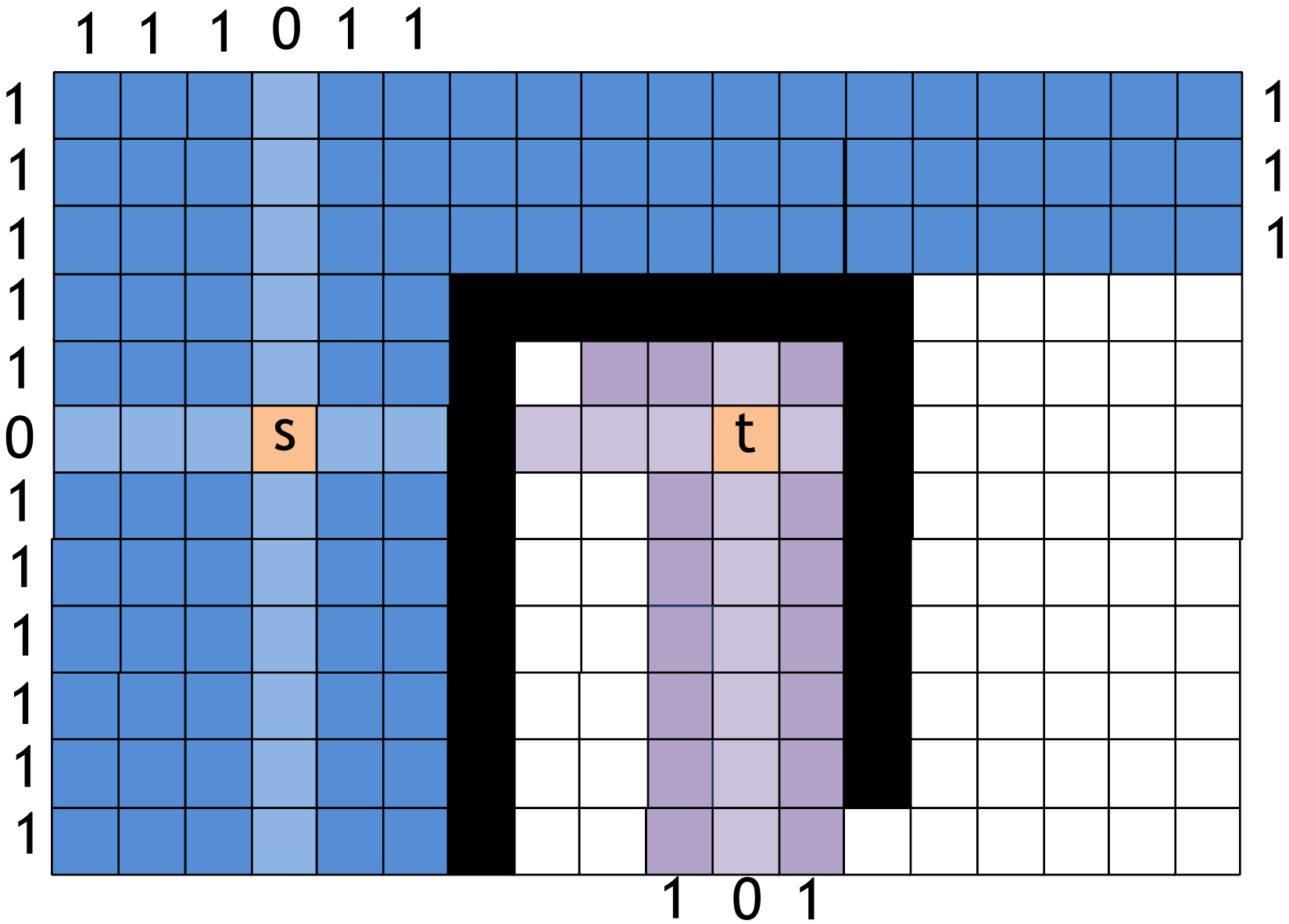
Sink Line Probe (Level 1)



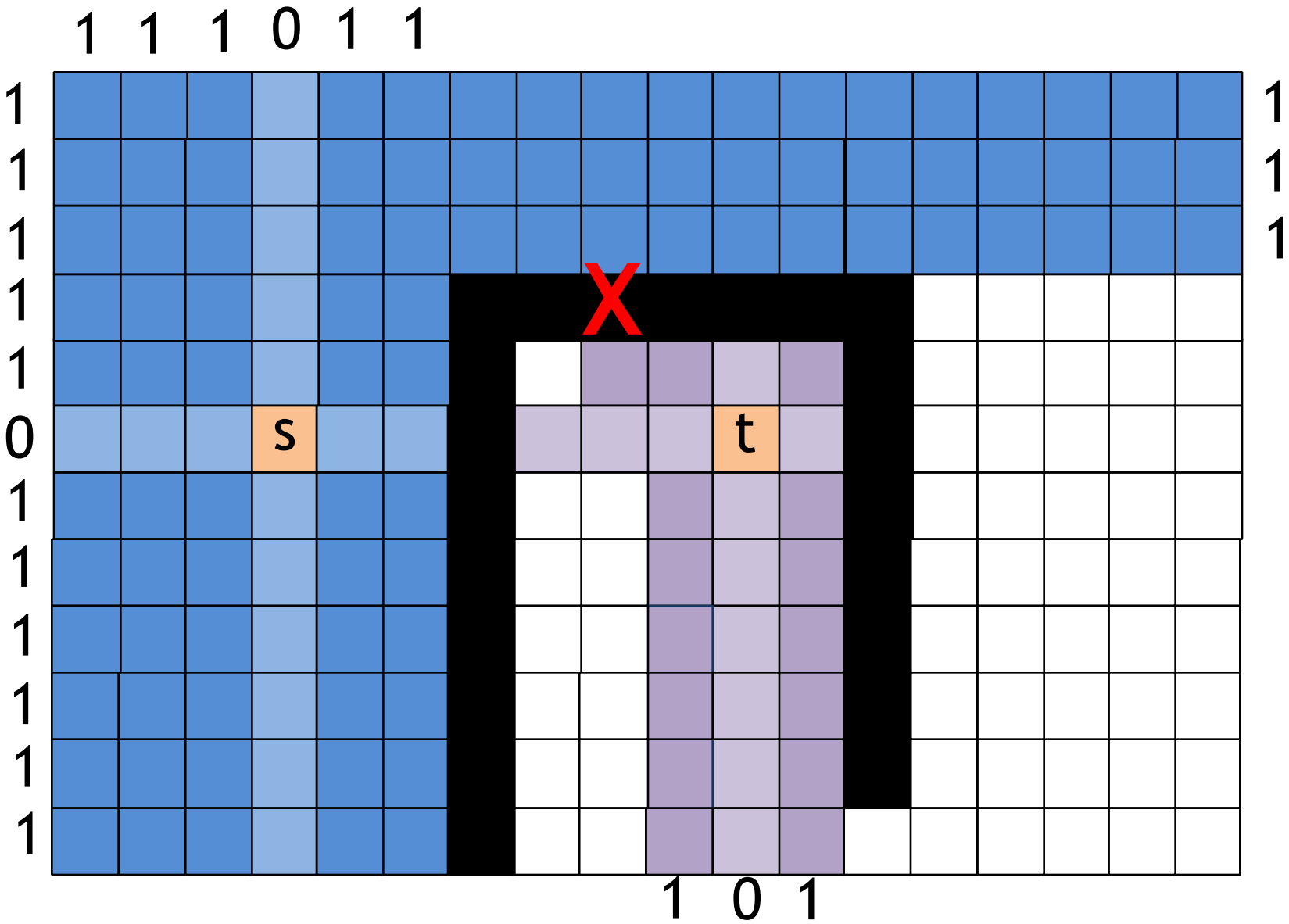
Sink Line Probe (Level 1)



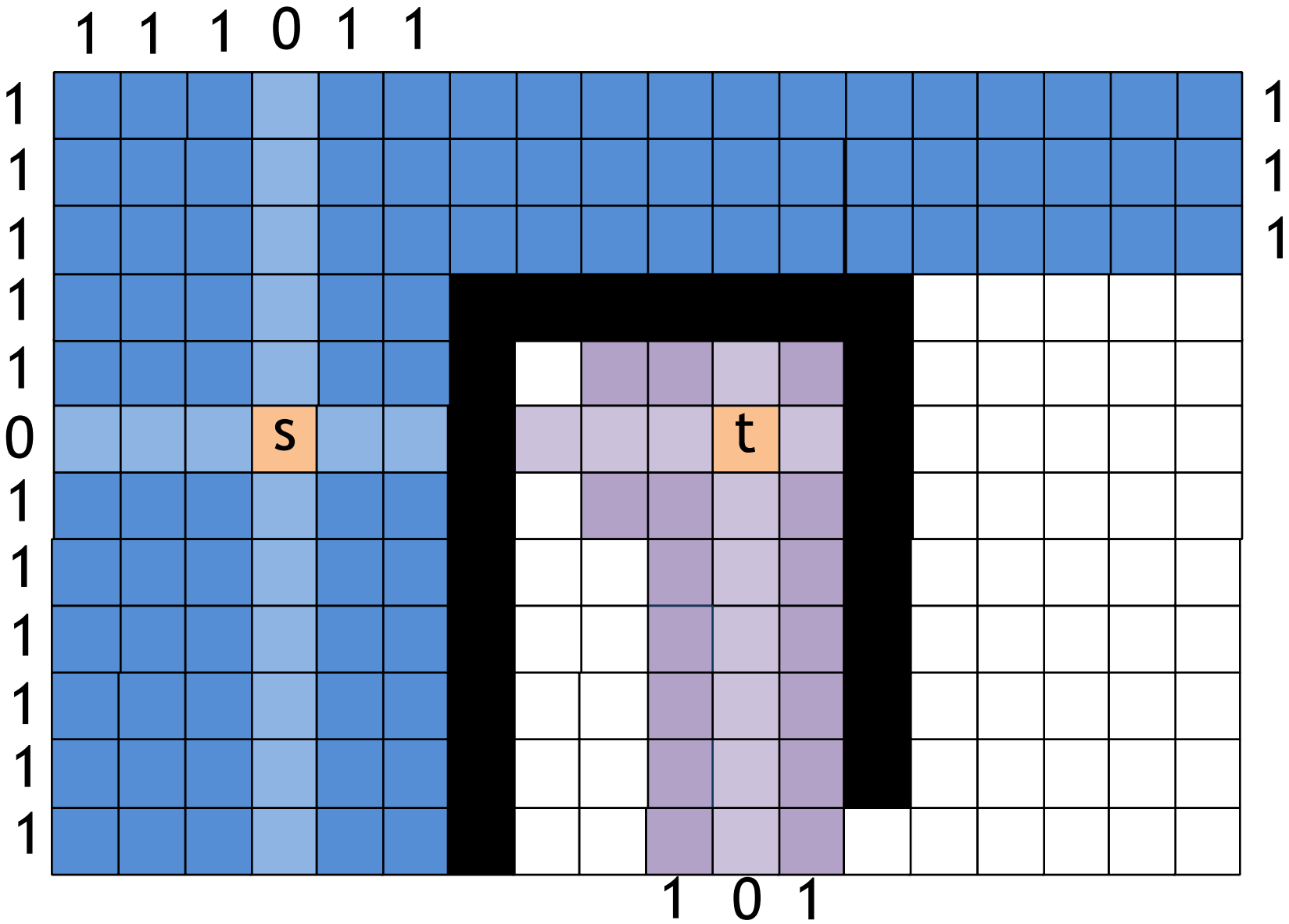
Sink Line Probe (Level 1)



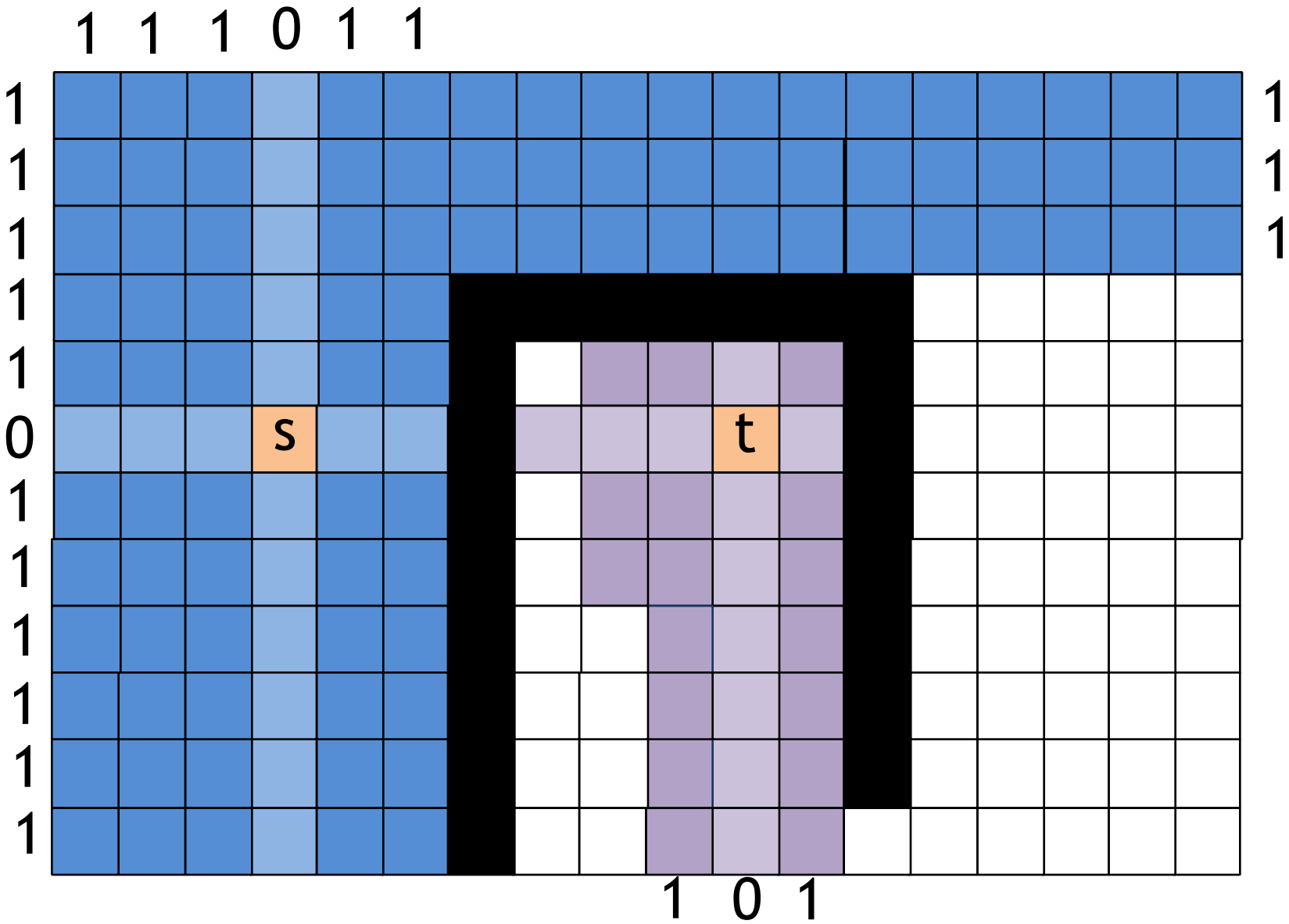
Sink Line Probe (Level 1)



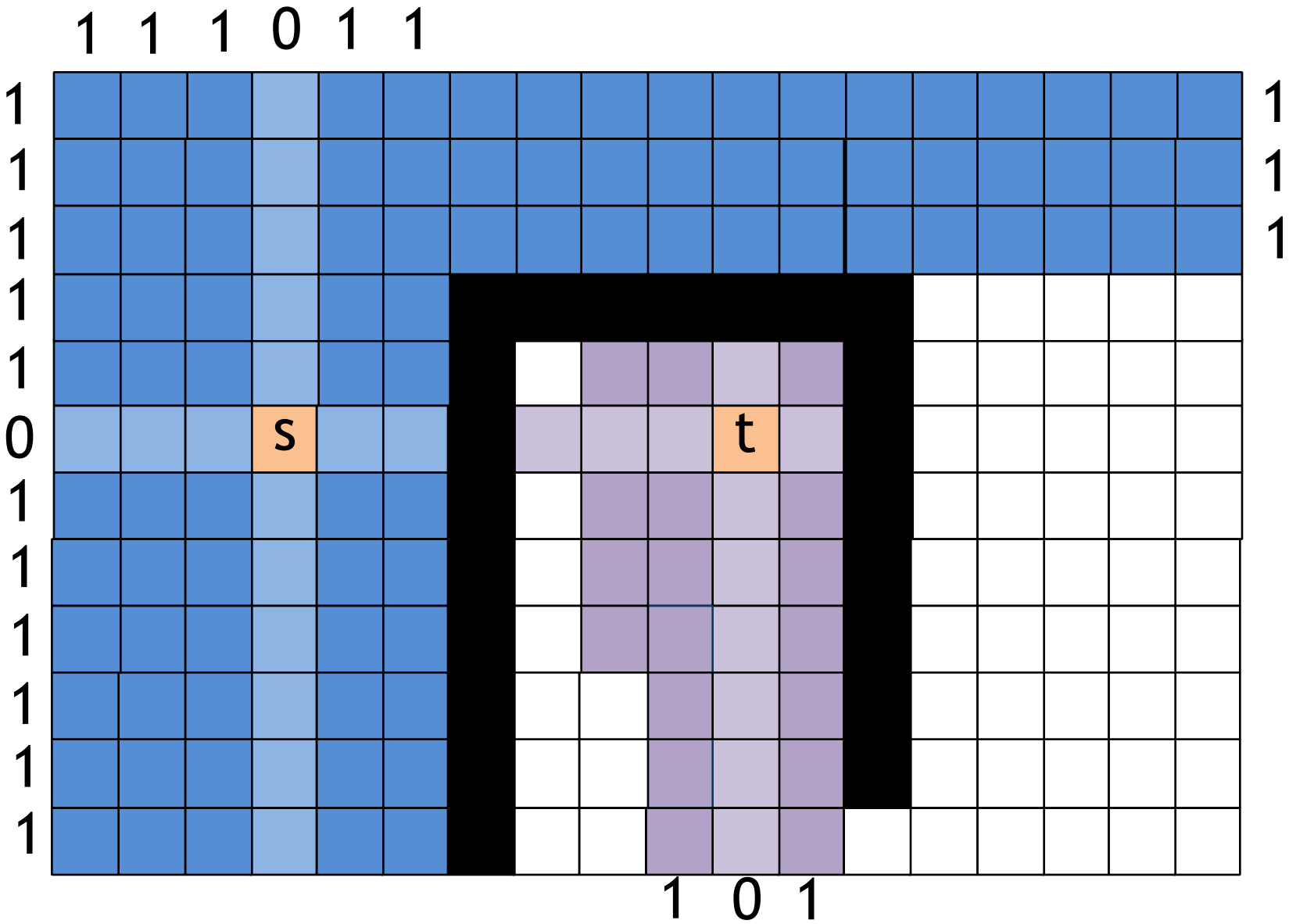
Sink Line Probe (Level 1)



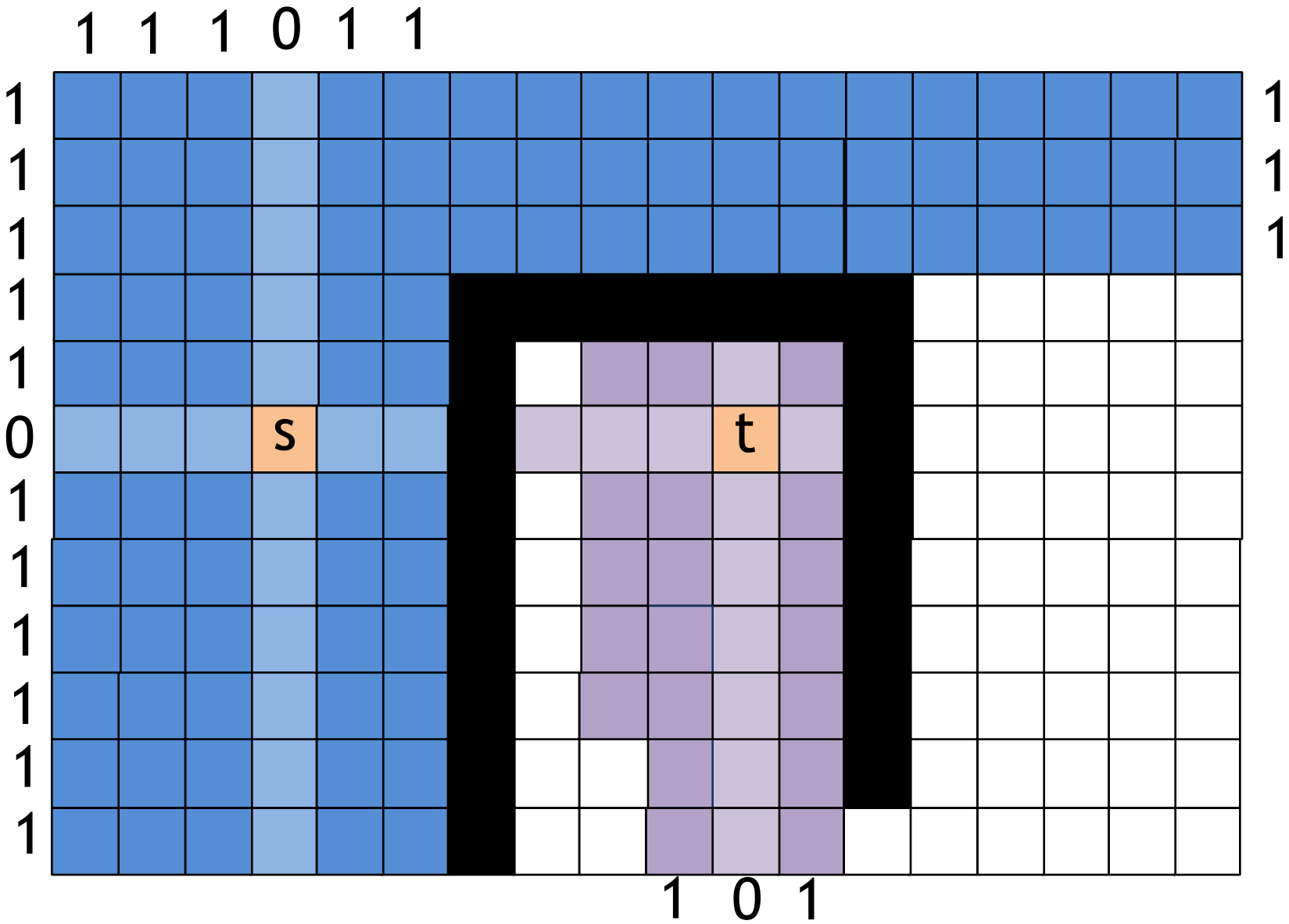
Sink Line Probe (Level 1)



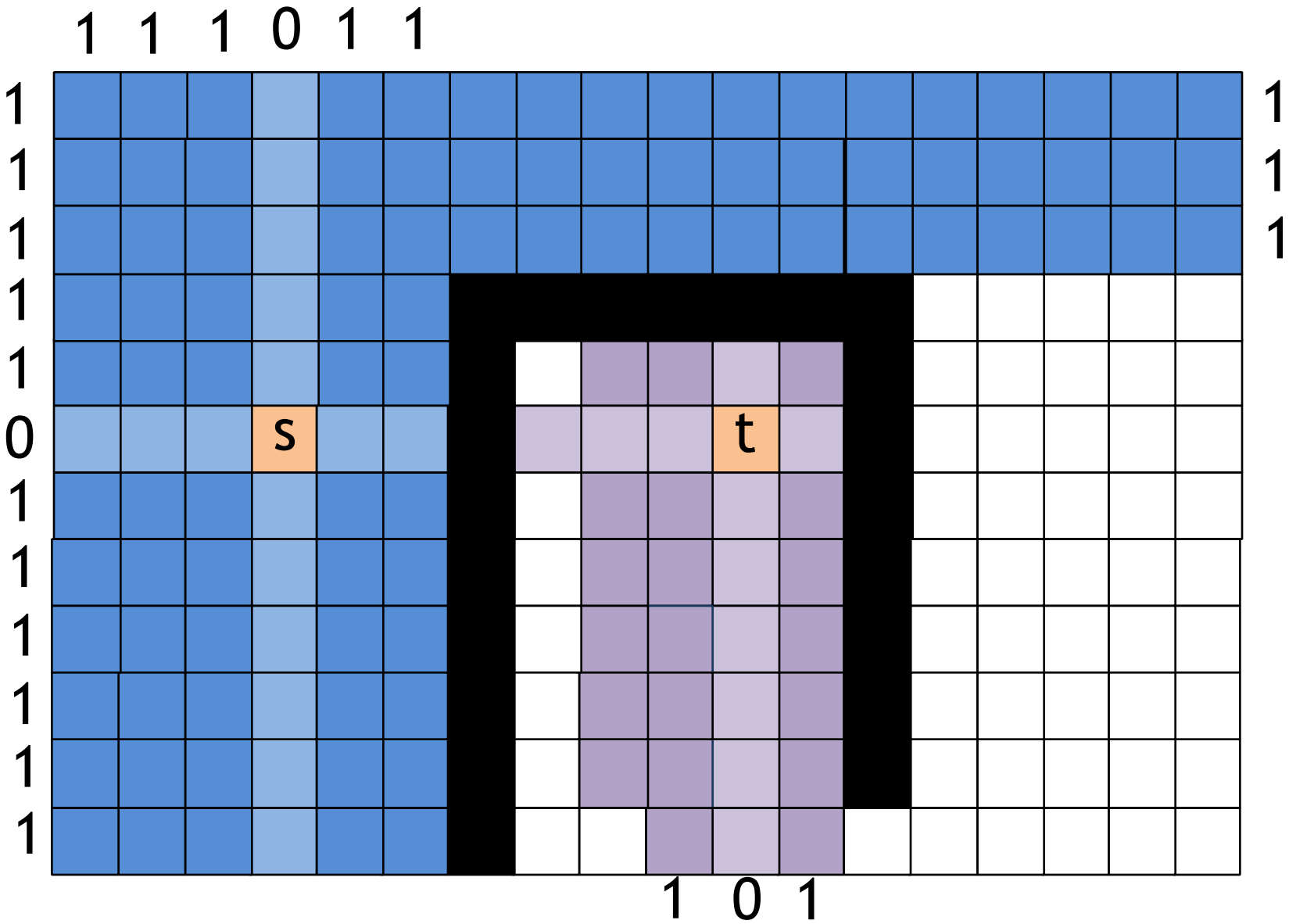
Sink Line Probe (Level 1)



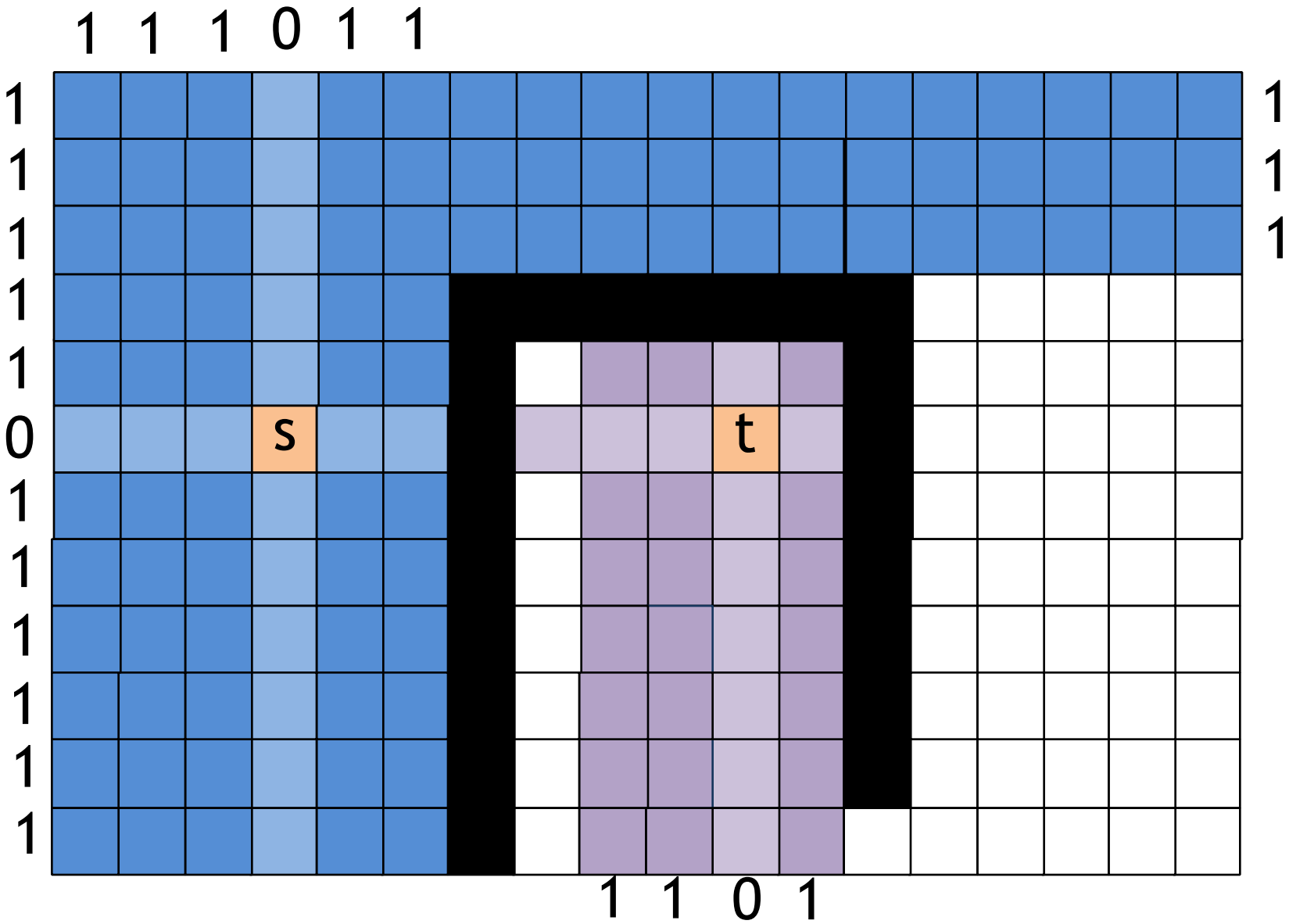
Sink Line Probe (Level 1)



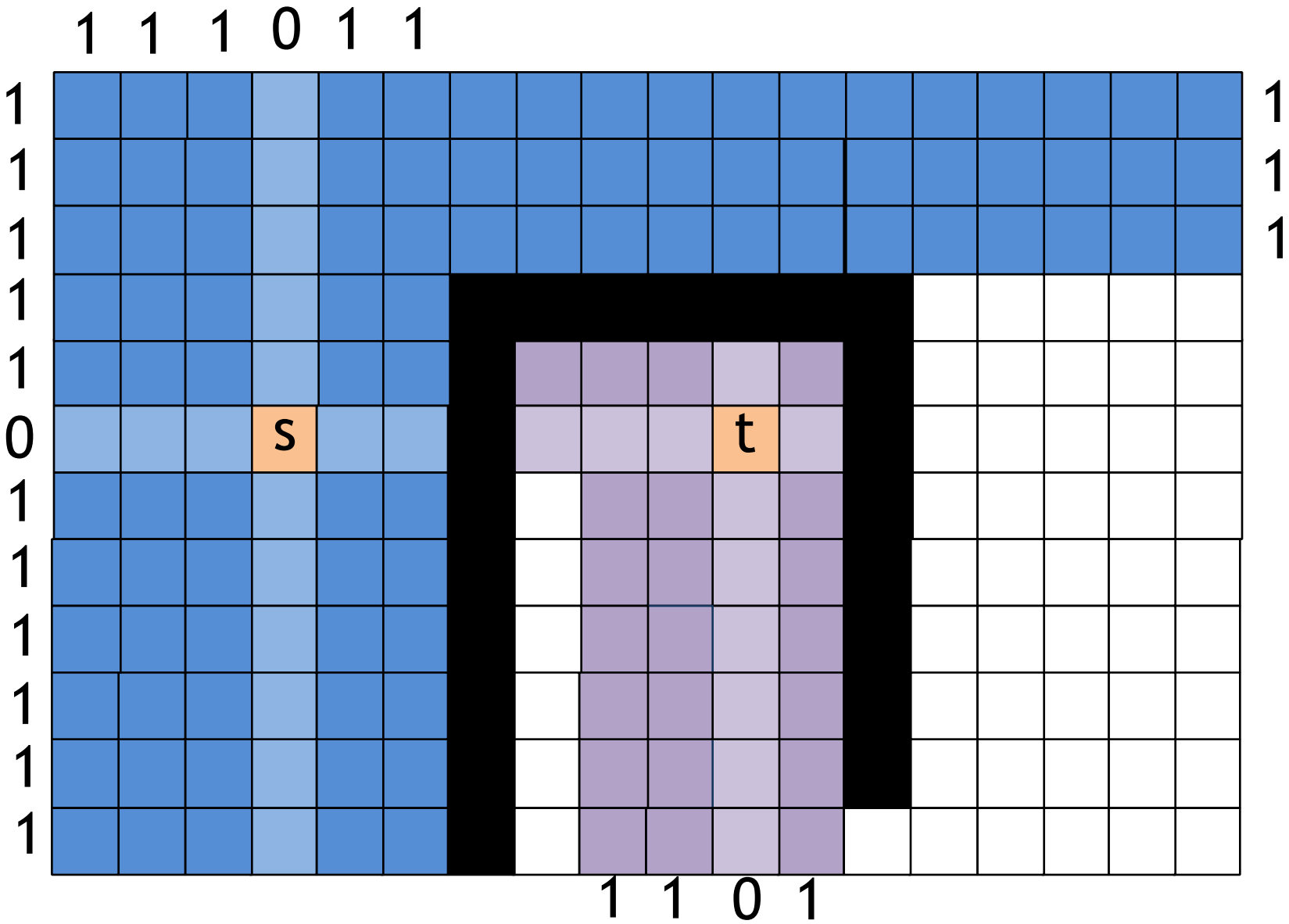
Sink Line Probe (Level 1)



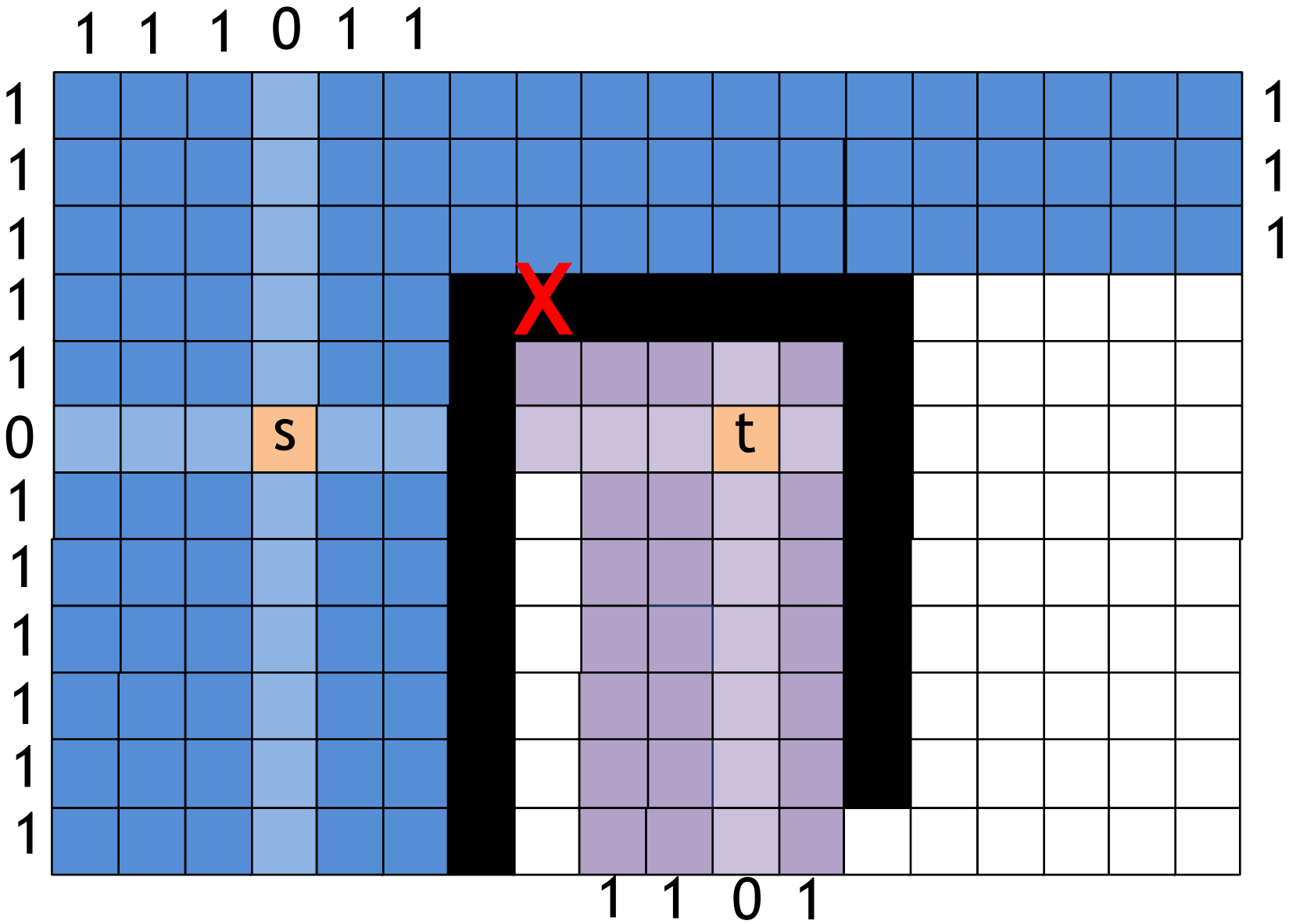
Sink Line Probe (Level 1)



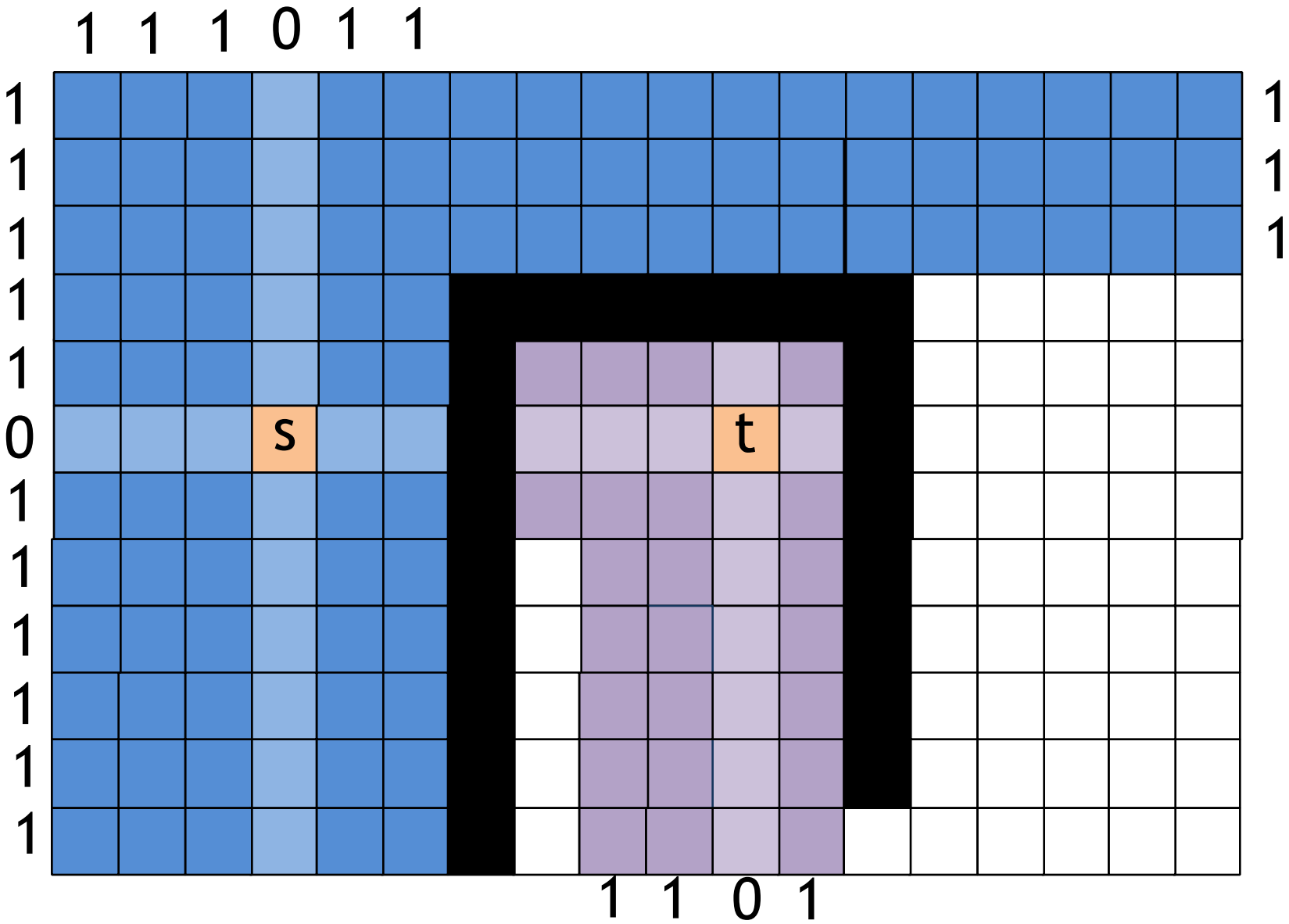
Sink Line Probe (Level 1)



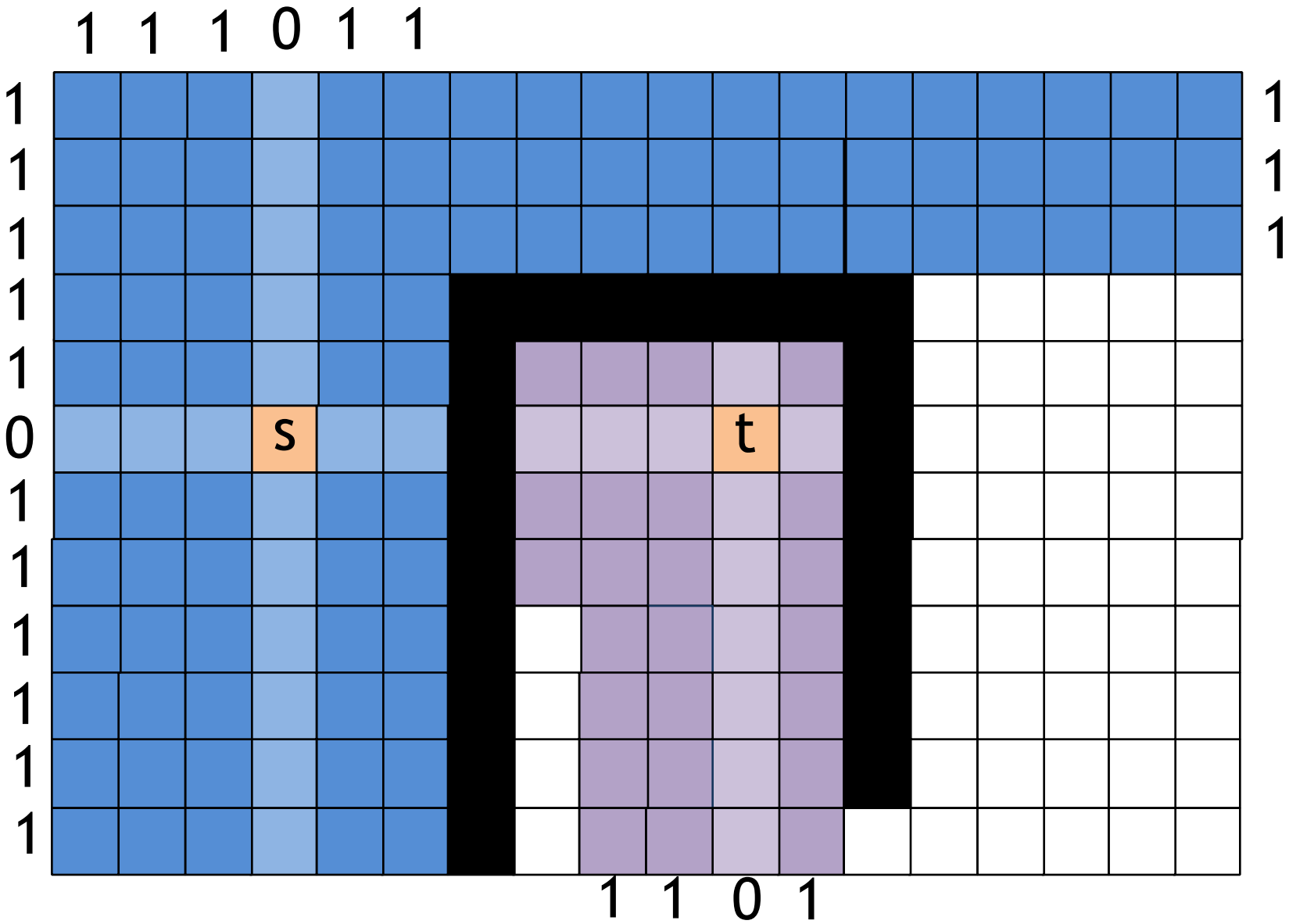
Sink Line Probe (Level 1)



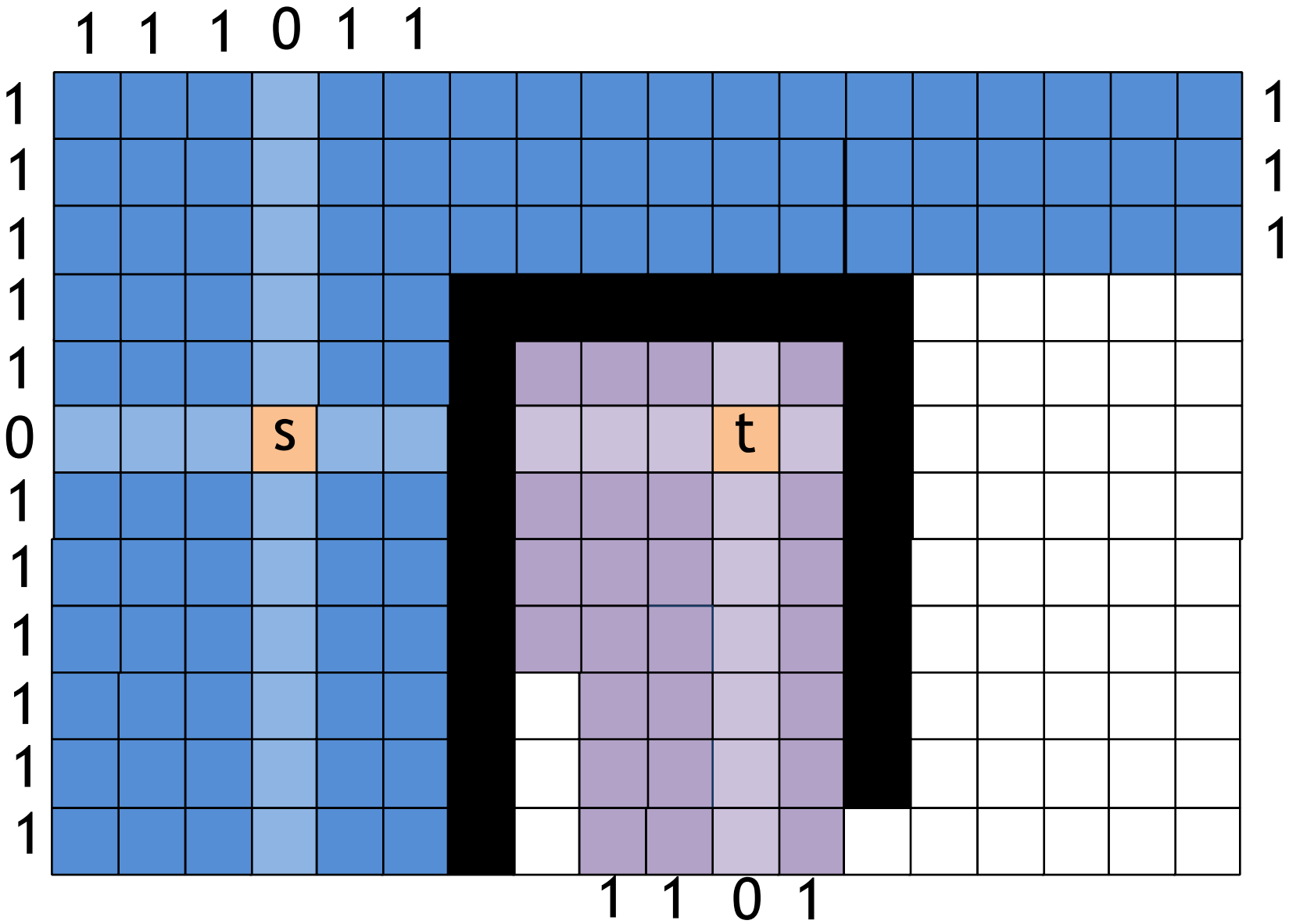
Sink Line Probe (Level 1)



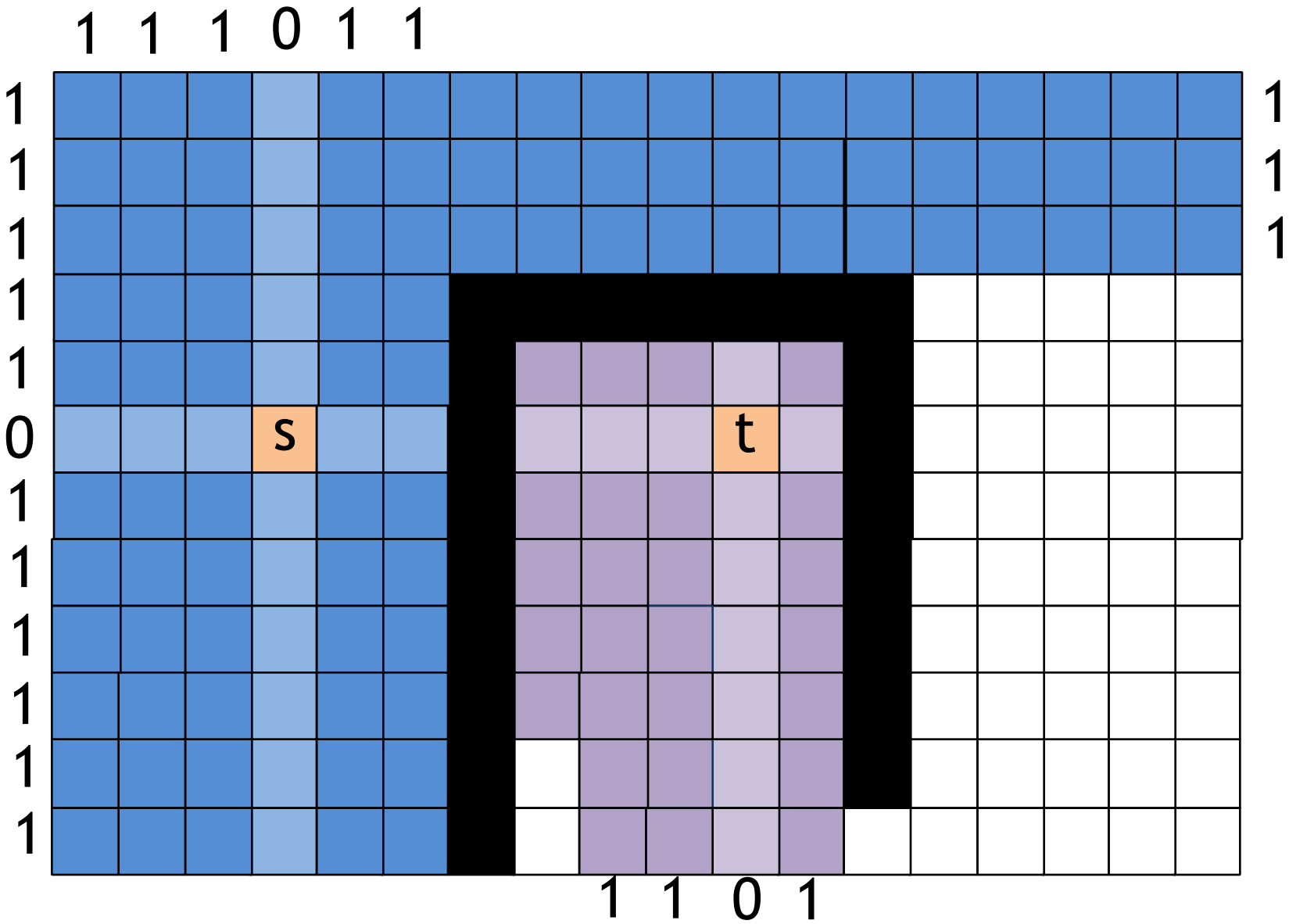
Sink Line Probe (Level 1)



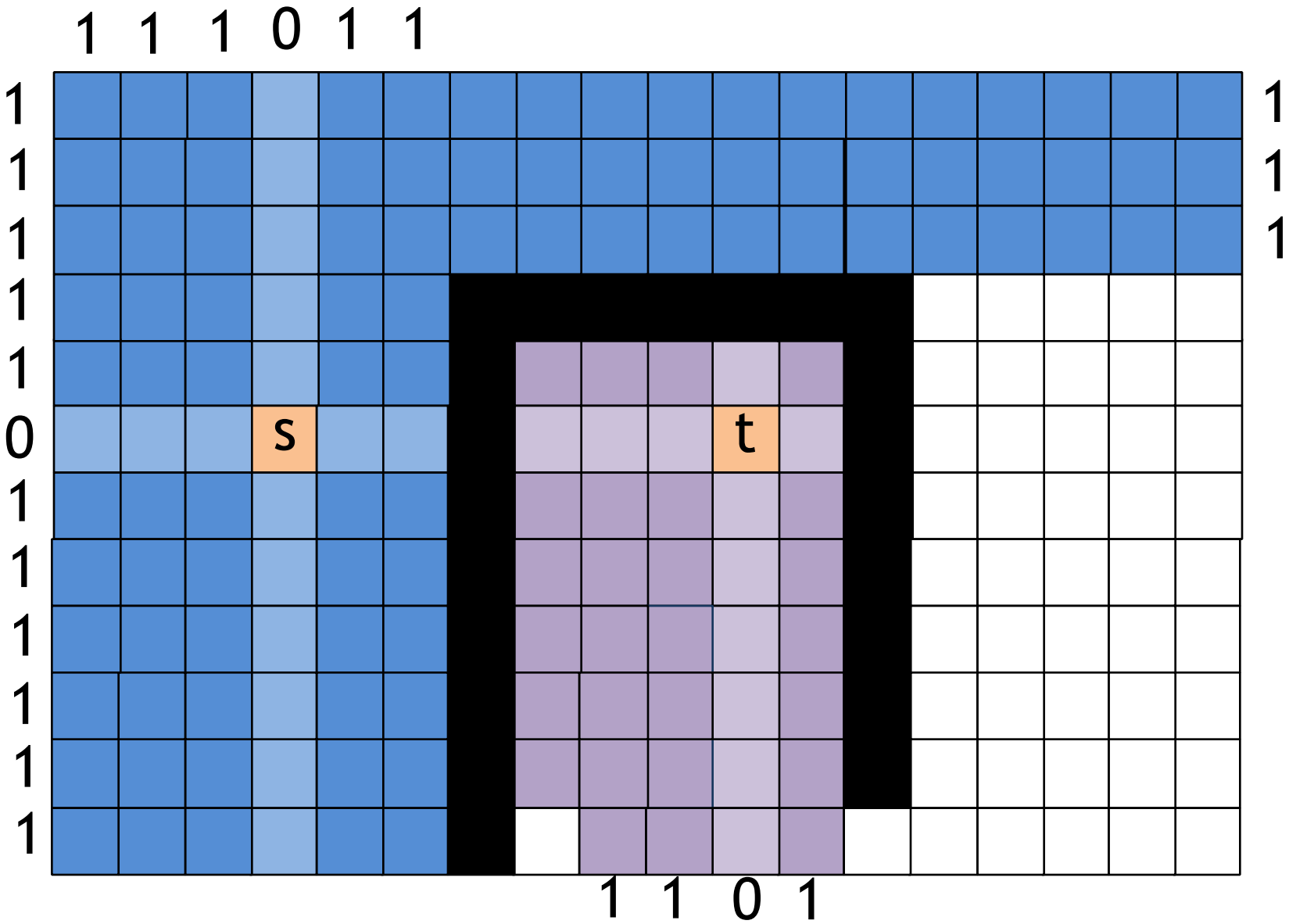
Sink Line Probe (Level 1)



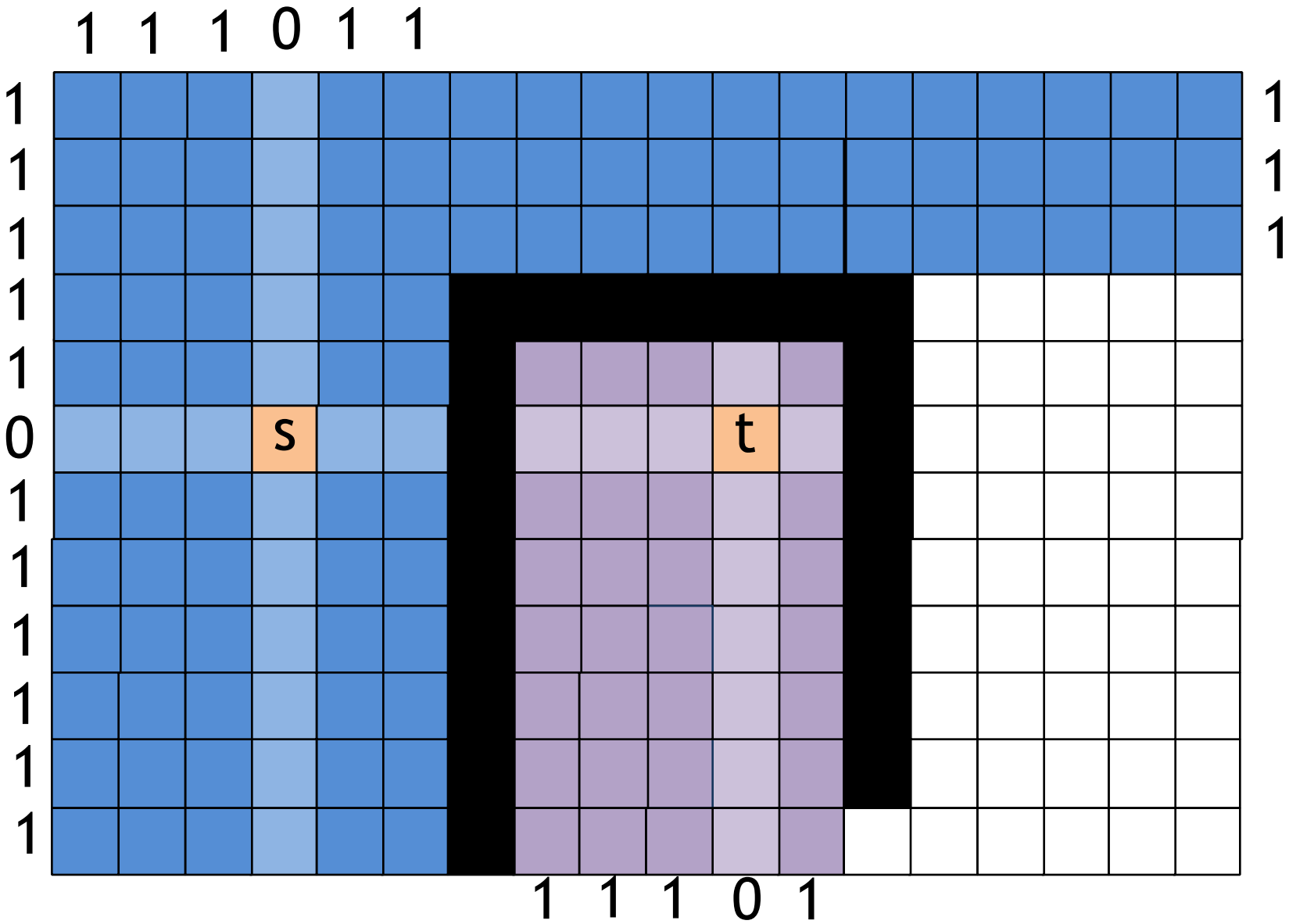
Sink Line Probe (Level 1)



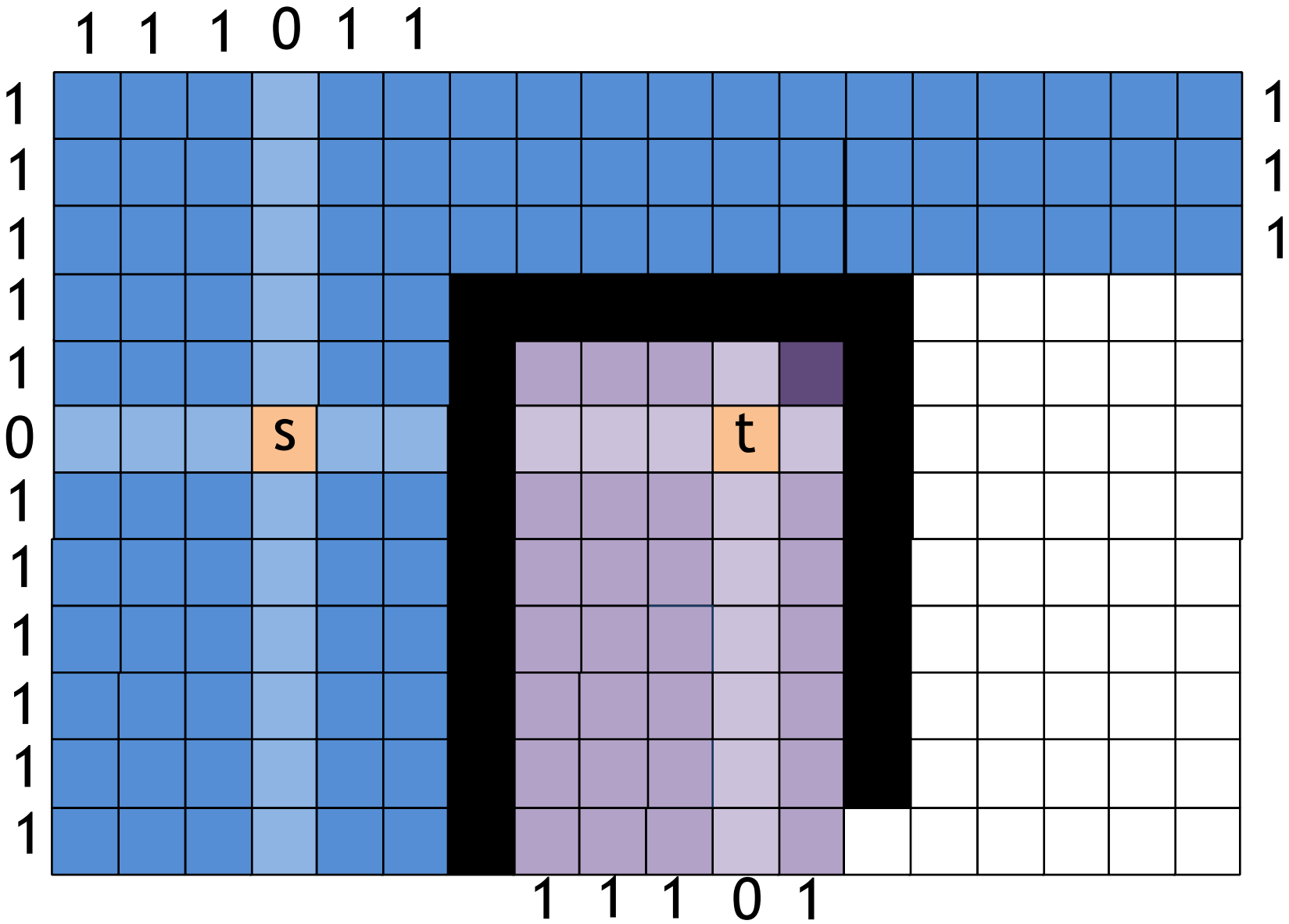
Sink Line Probe (Level 1)



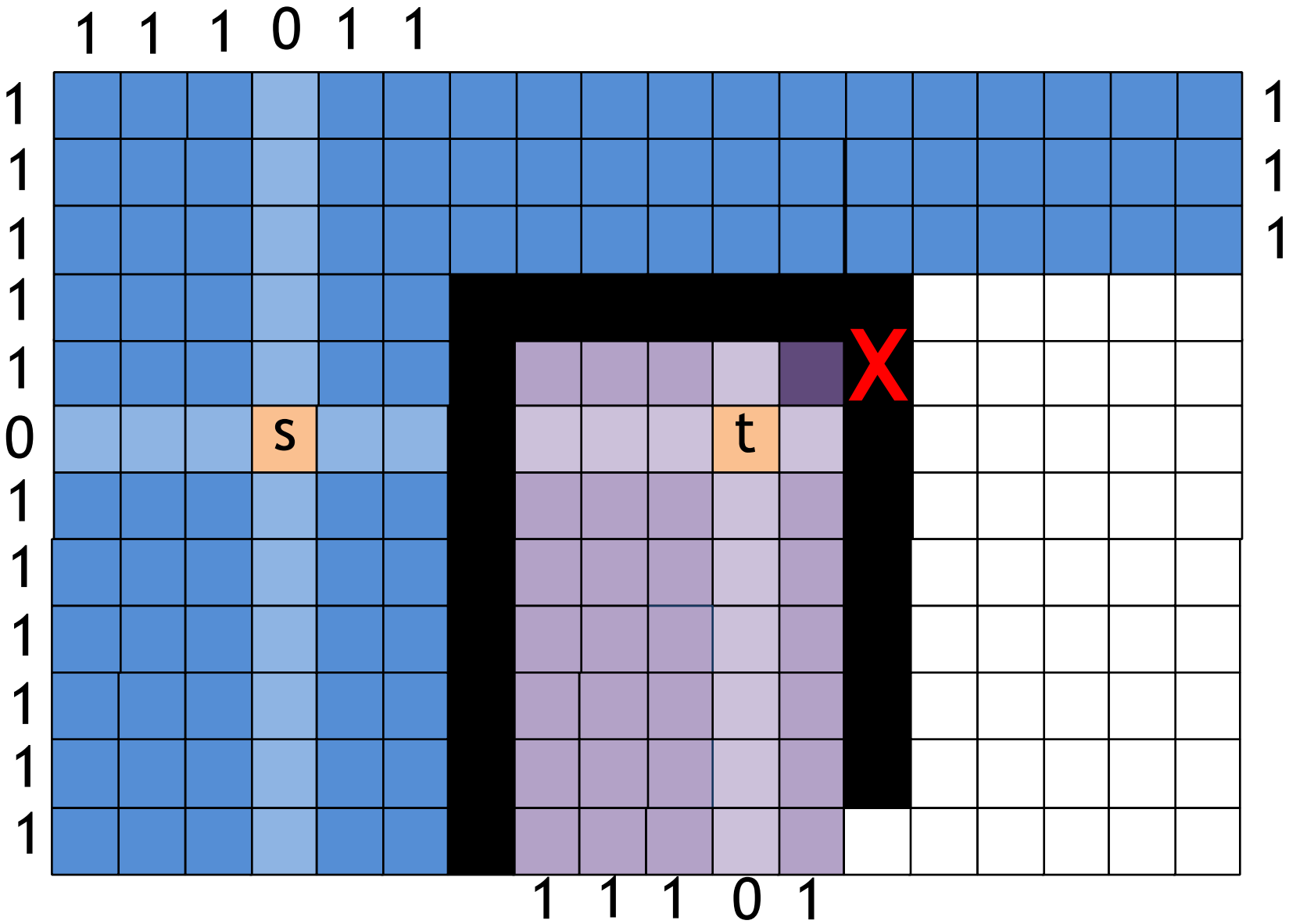
Sink Line Probe (Level 1)



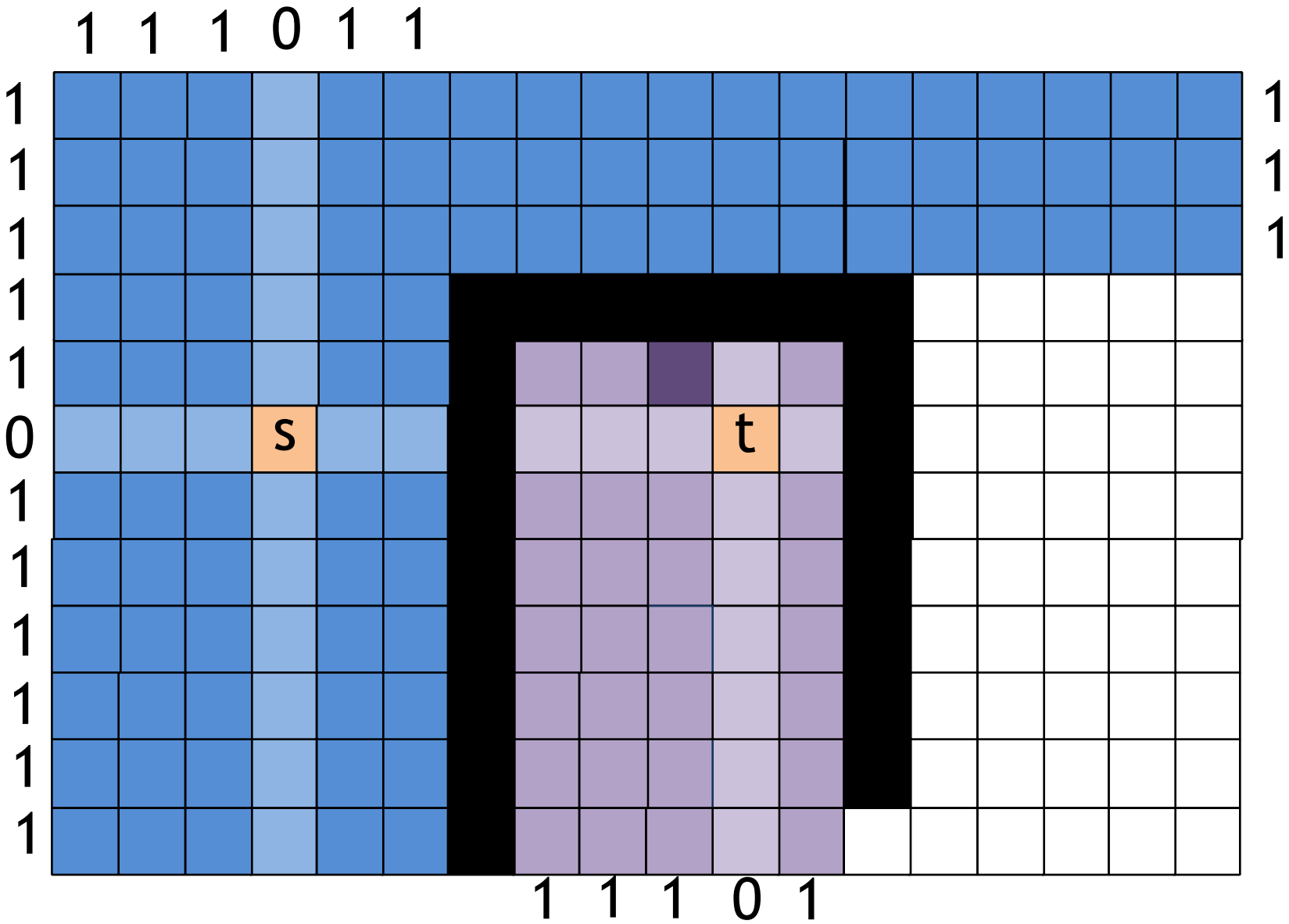
Sink Line Probe (Level 1)



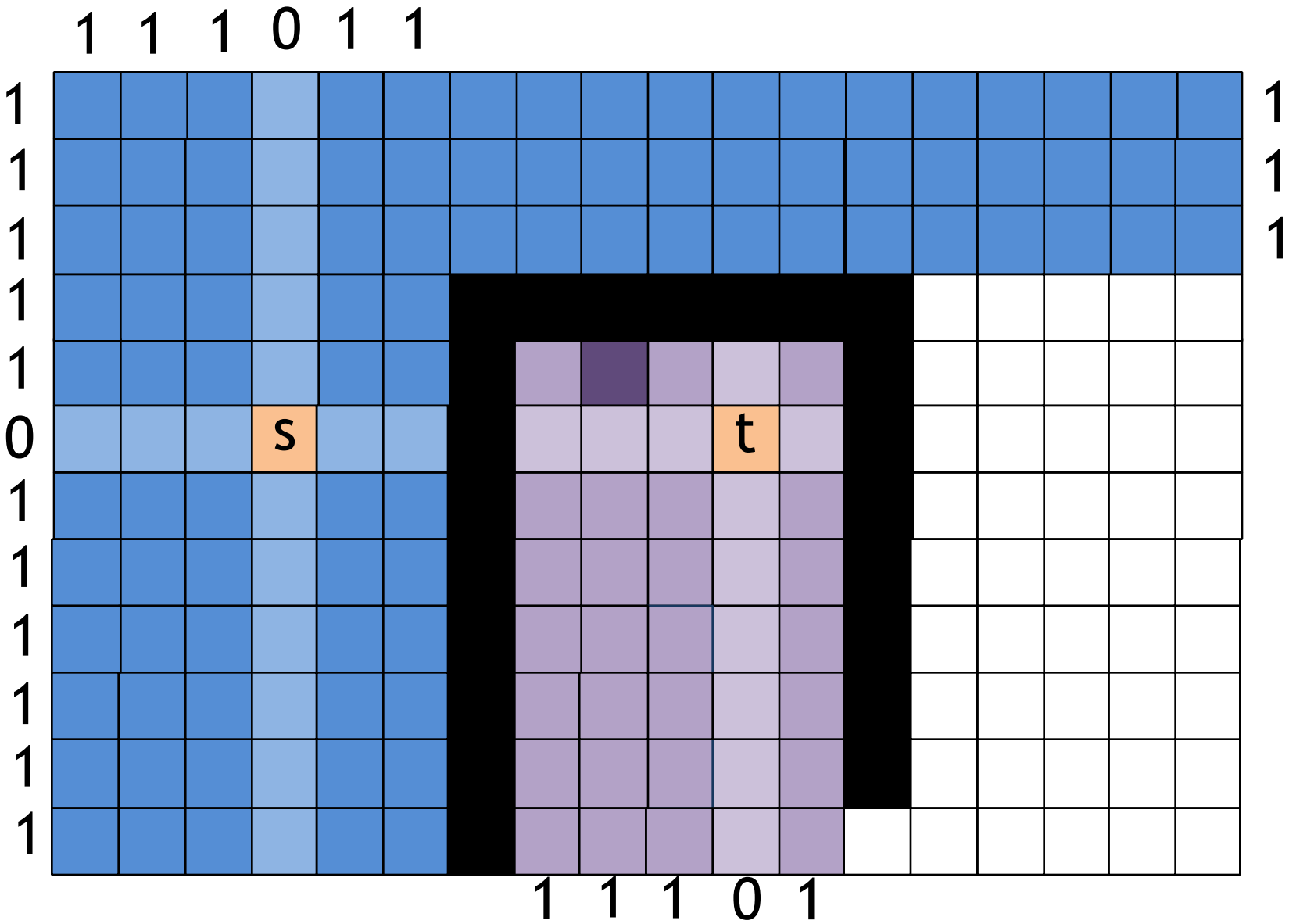
Sink Line Probe (Level 1)



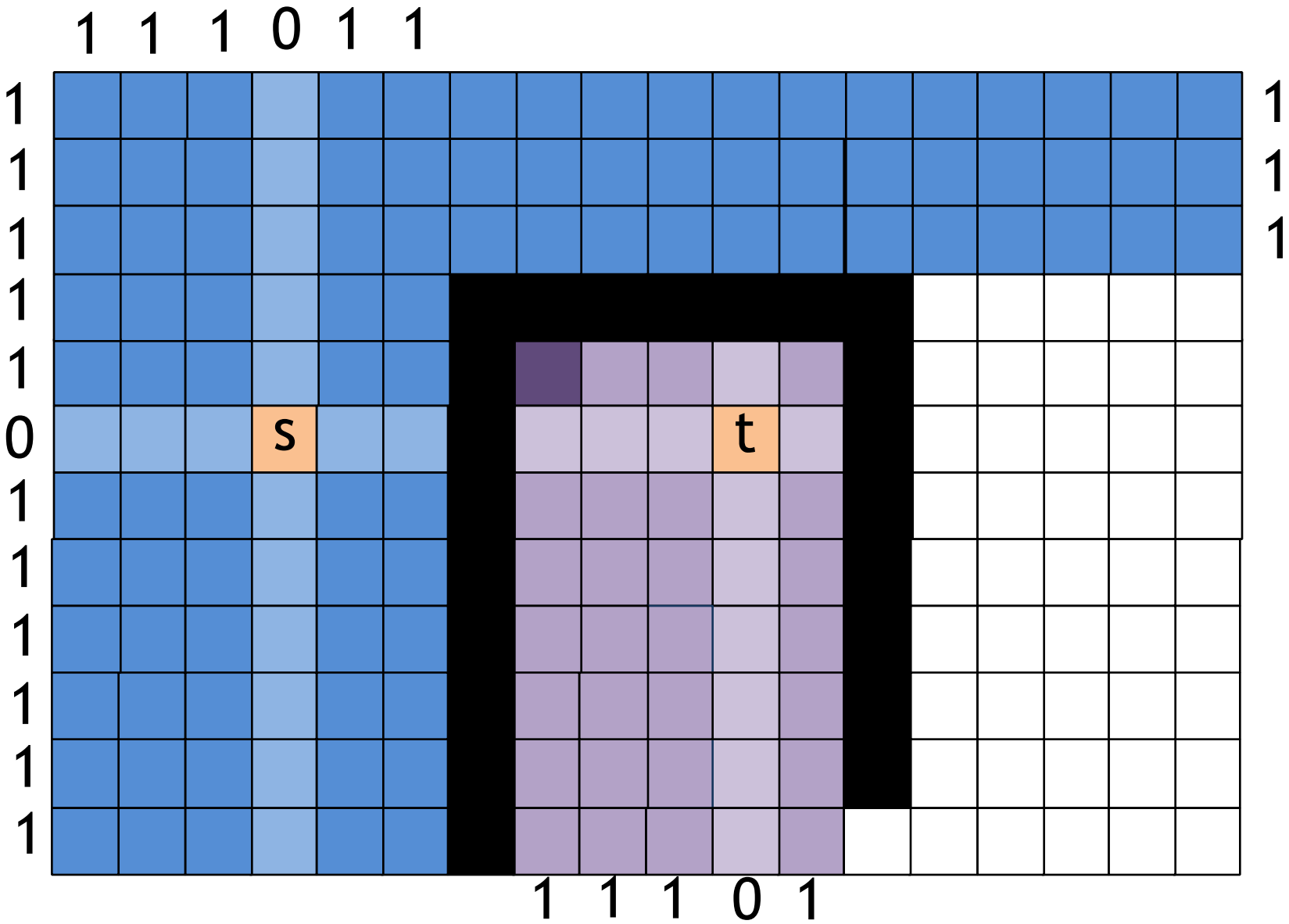
Sink Line Probe (Level 1)



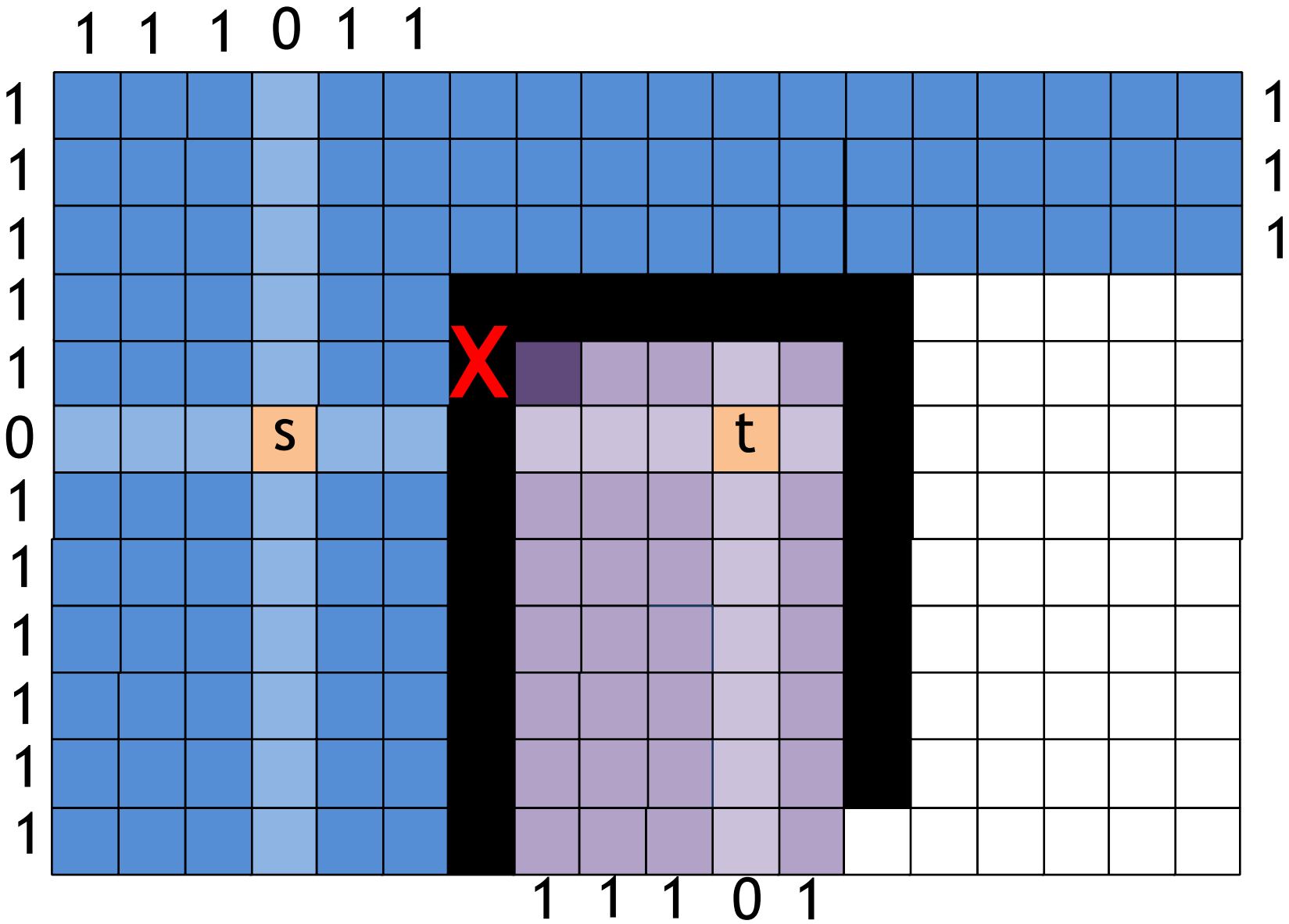
Sink Line Probe (Level 1)



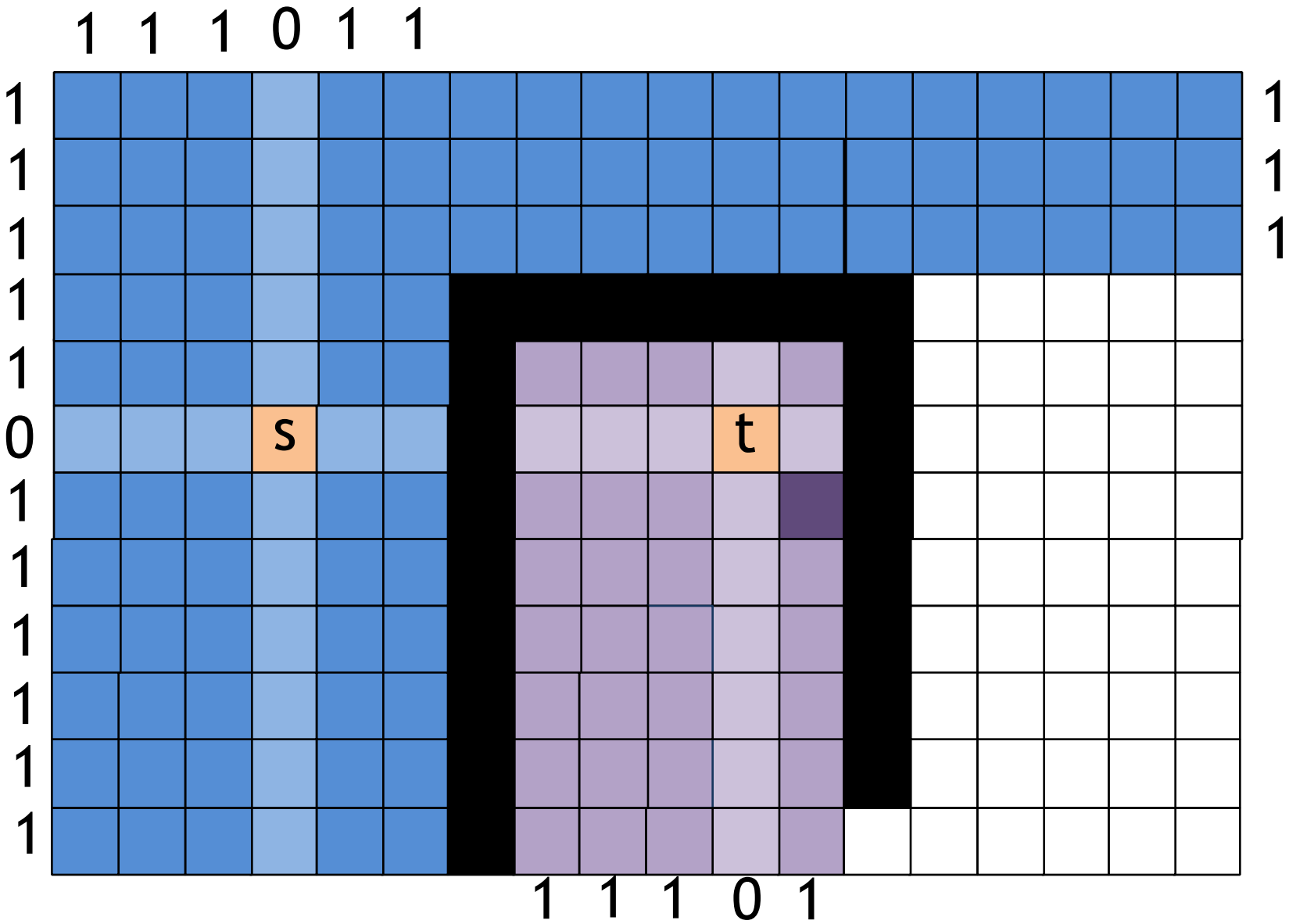
Sink Line Probe (Level 1)



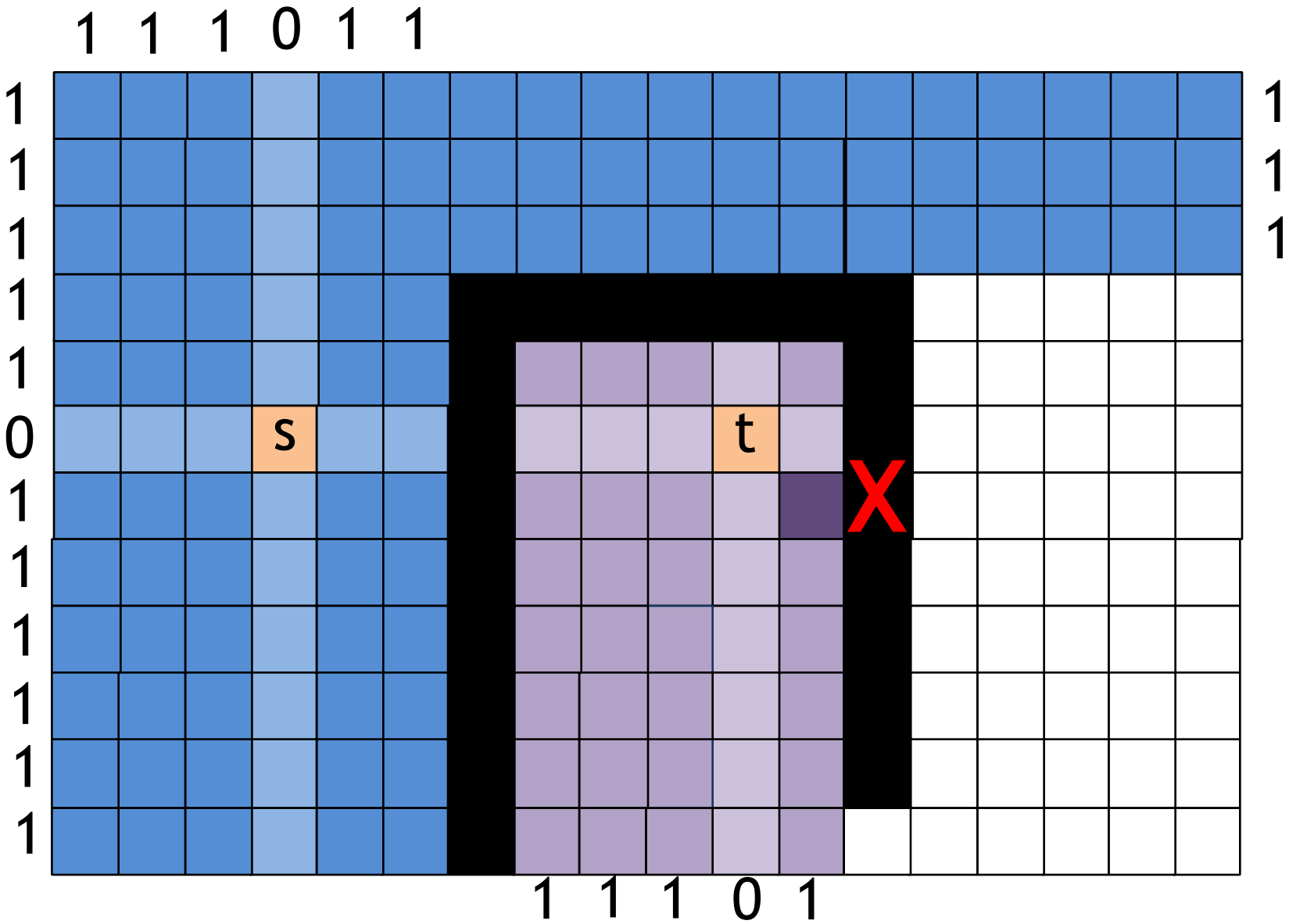
Sink Line Probe (Level 1)



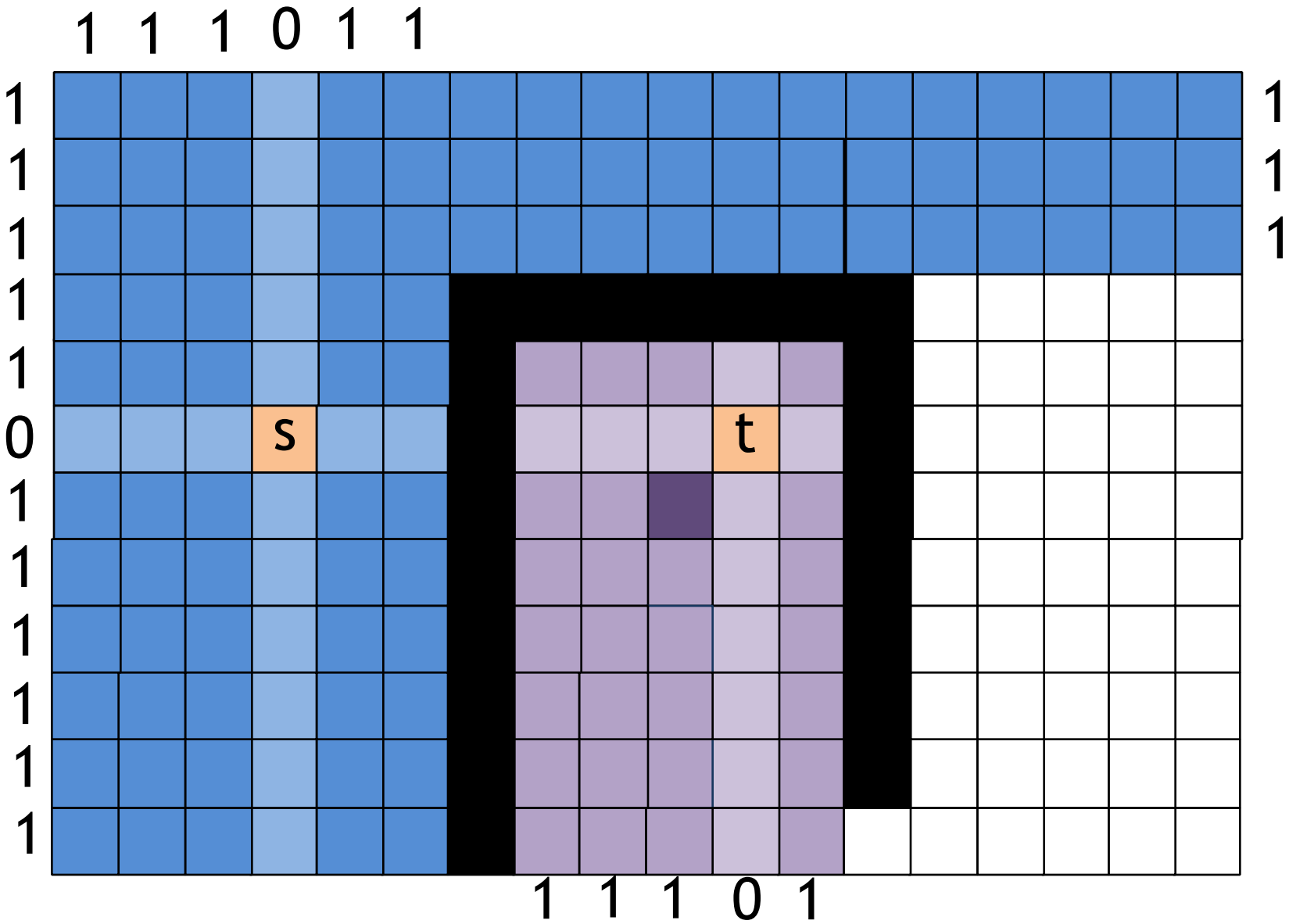
Sink Line Probe (Level 1)



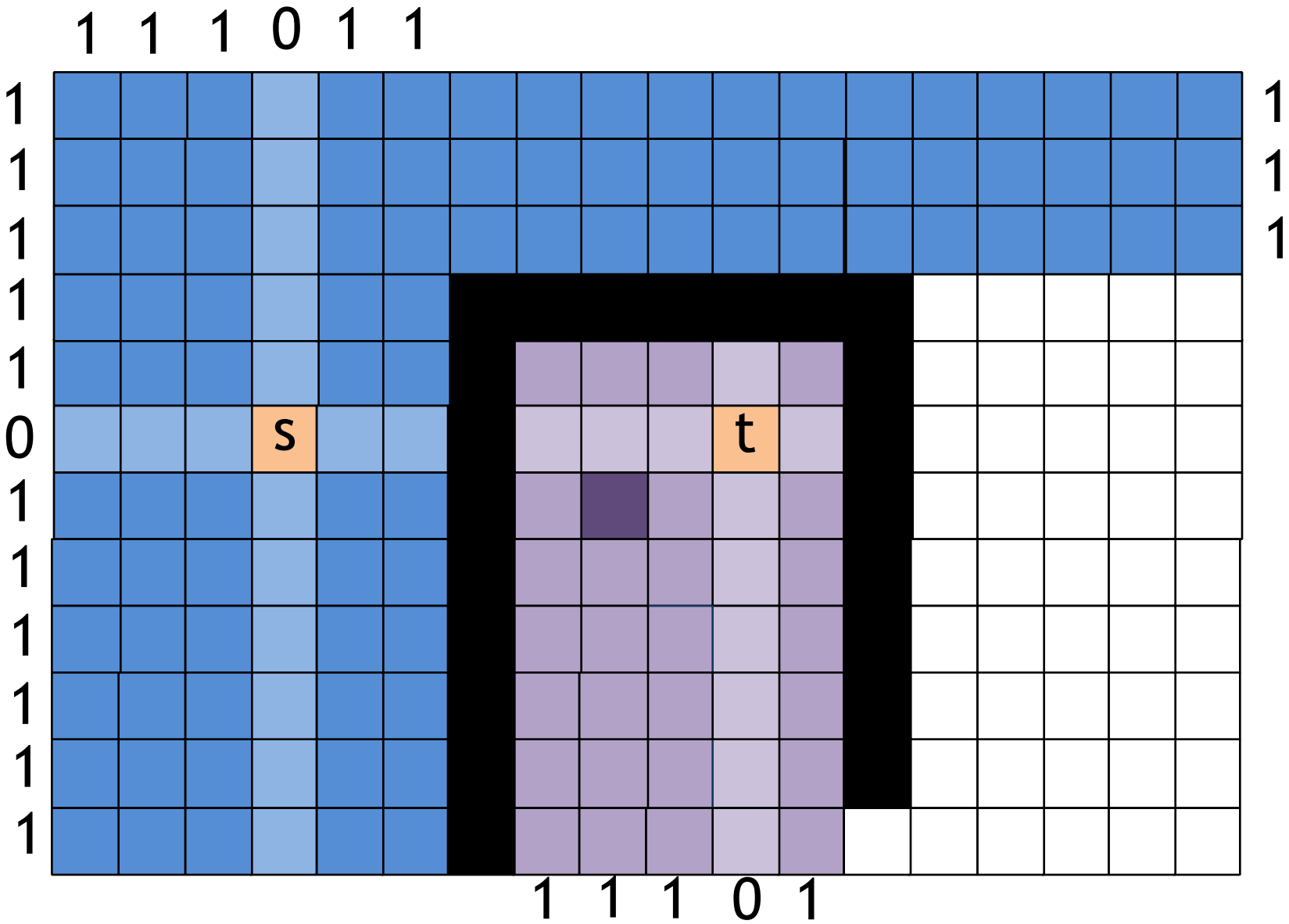
Sink Line Probe (Level 1)



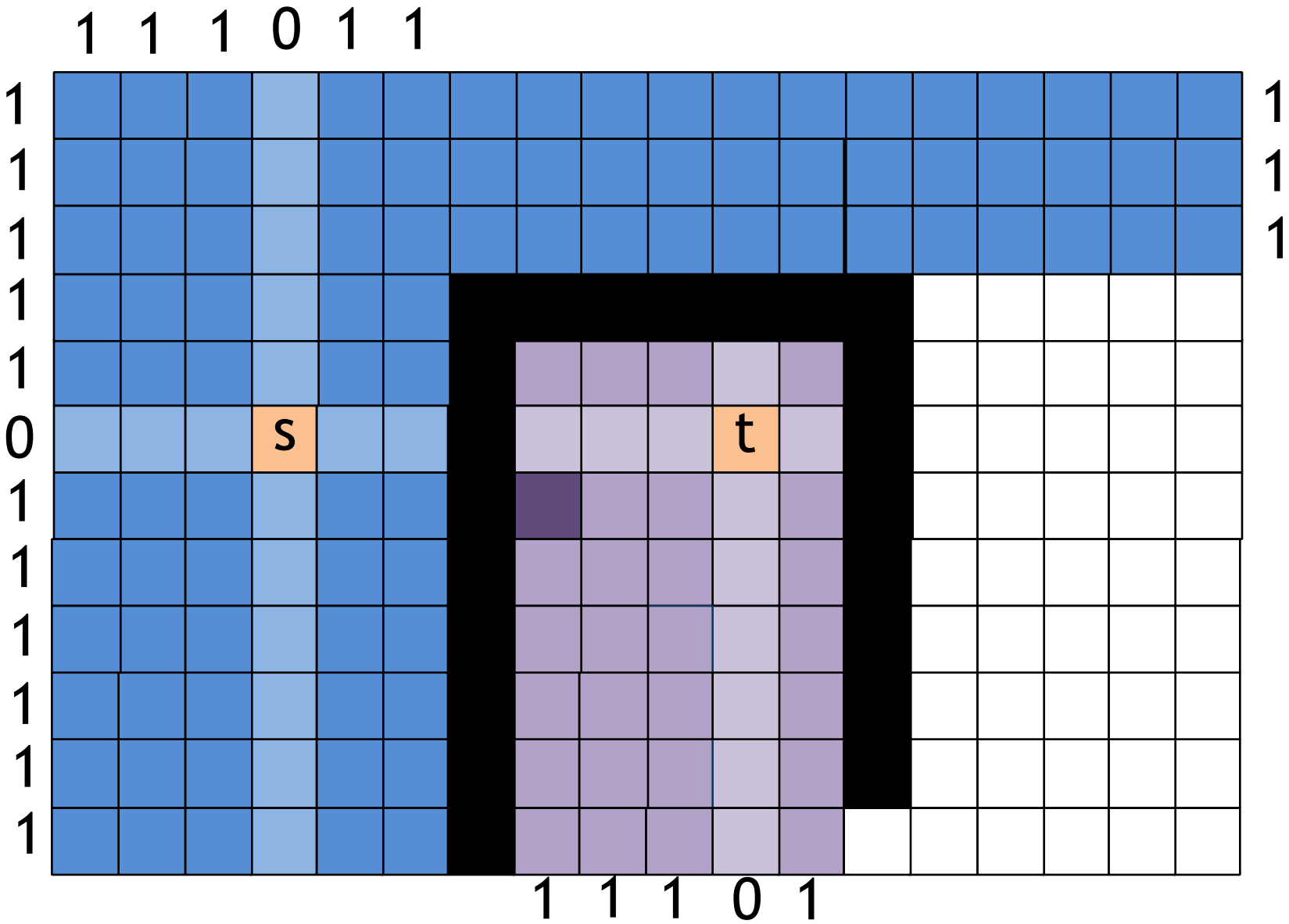
Sink Line Probe (Level 1)



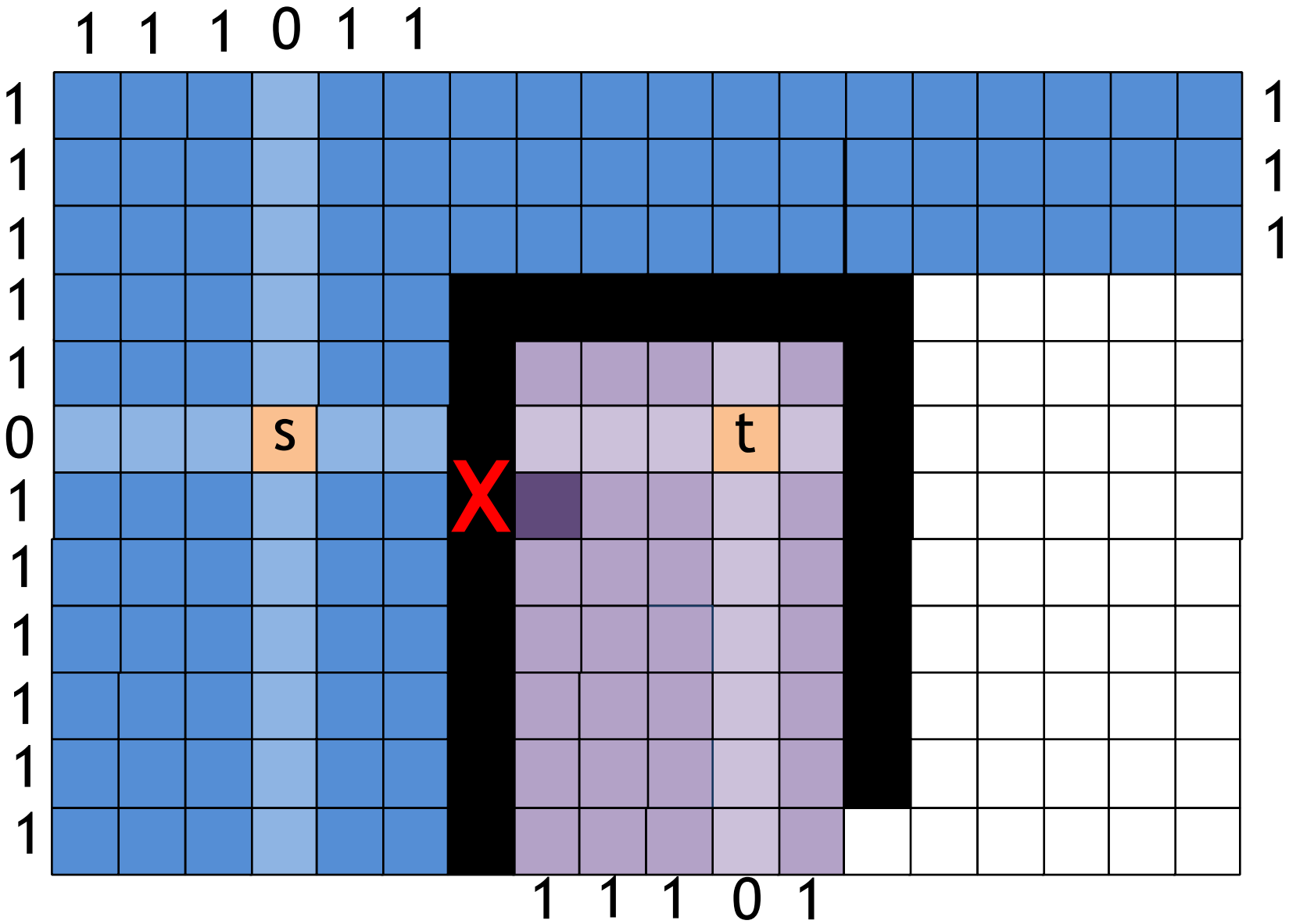
Sink Line Probe (Level 1)



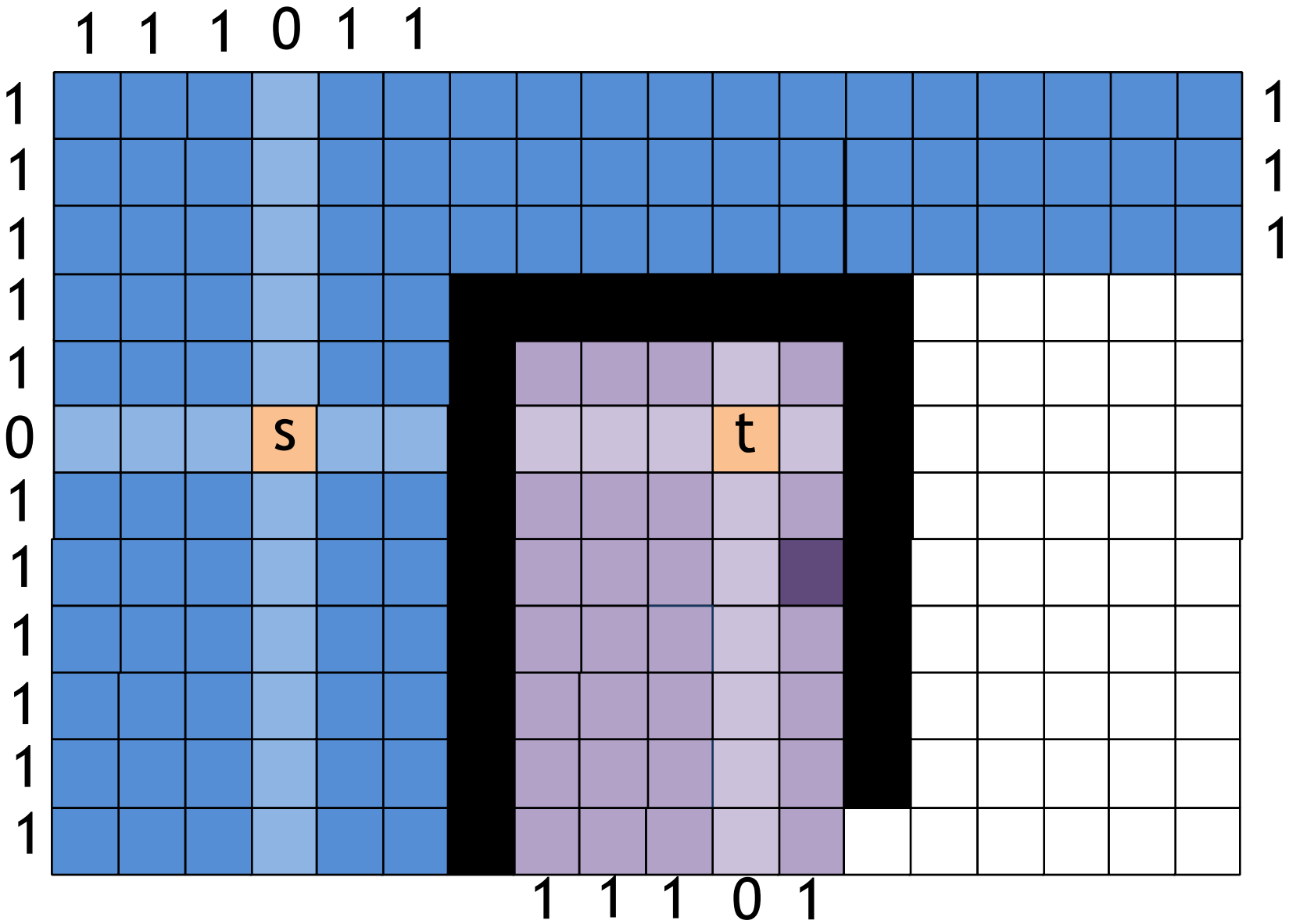
Sink Line Probe (Level 1)



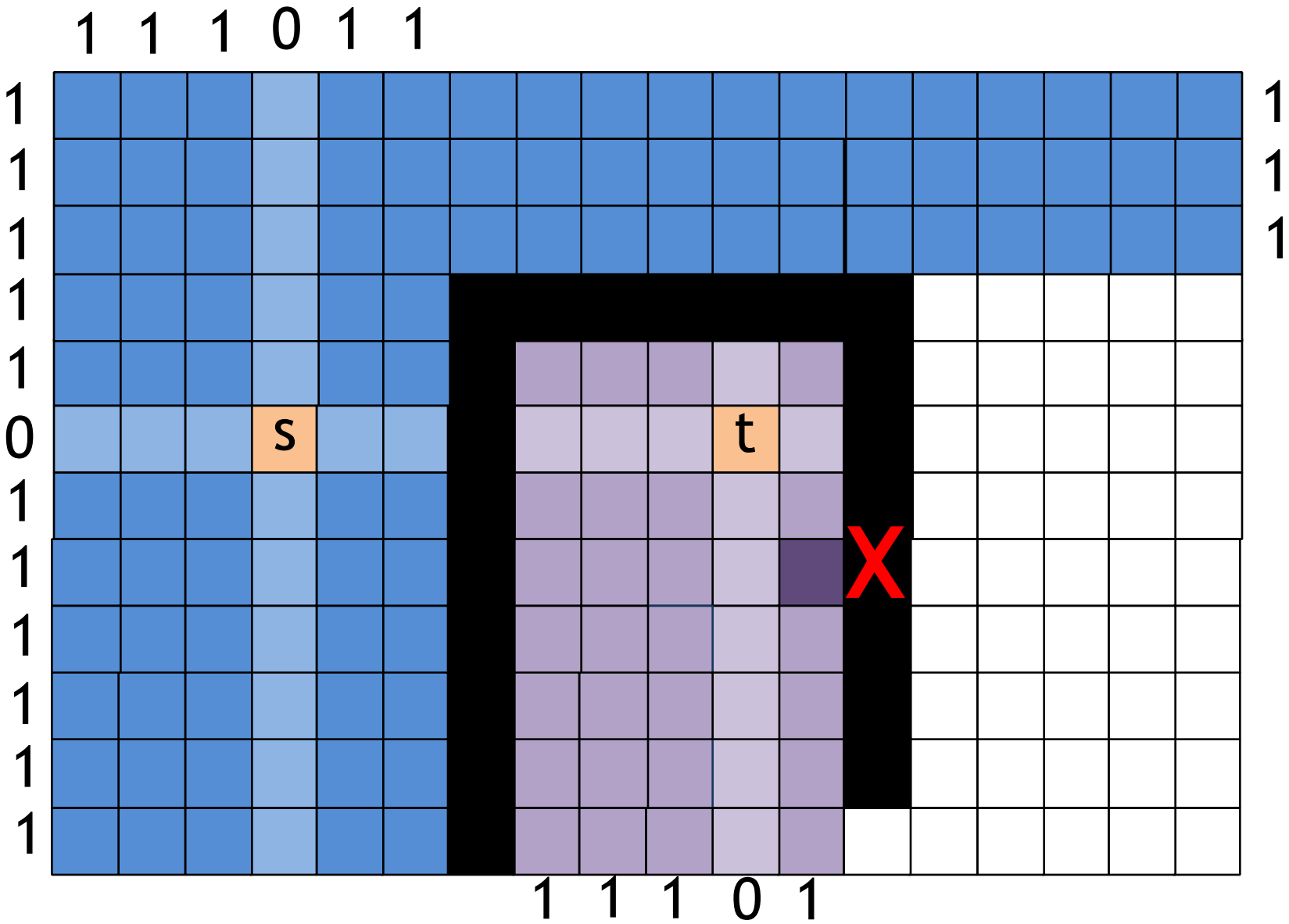
Sink Line Probe (Level 1)



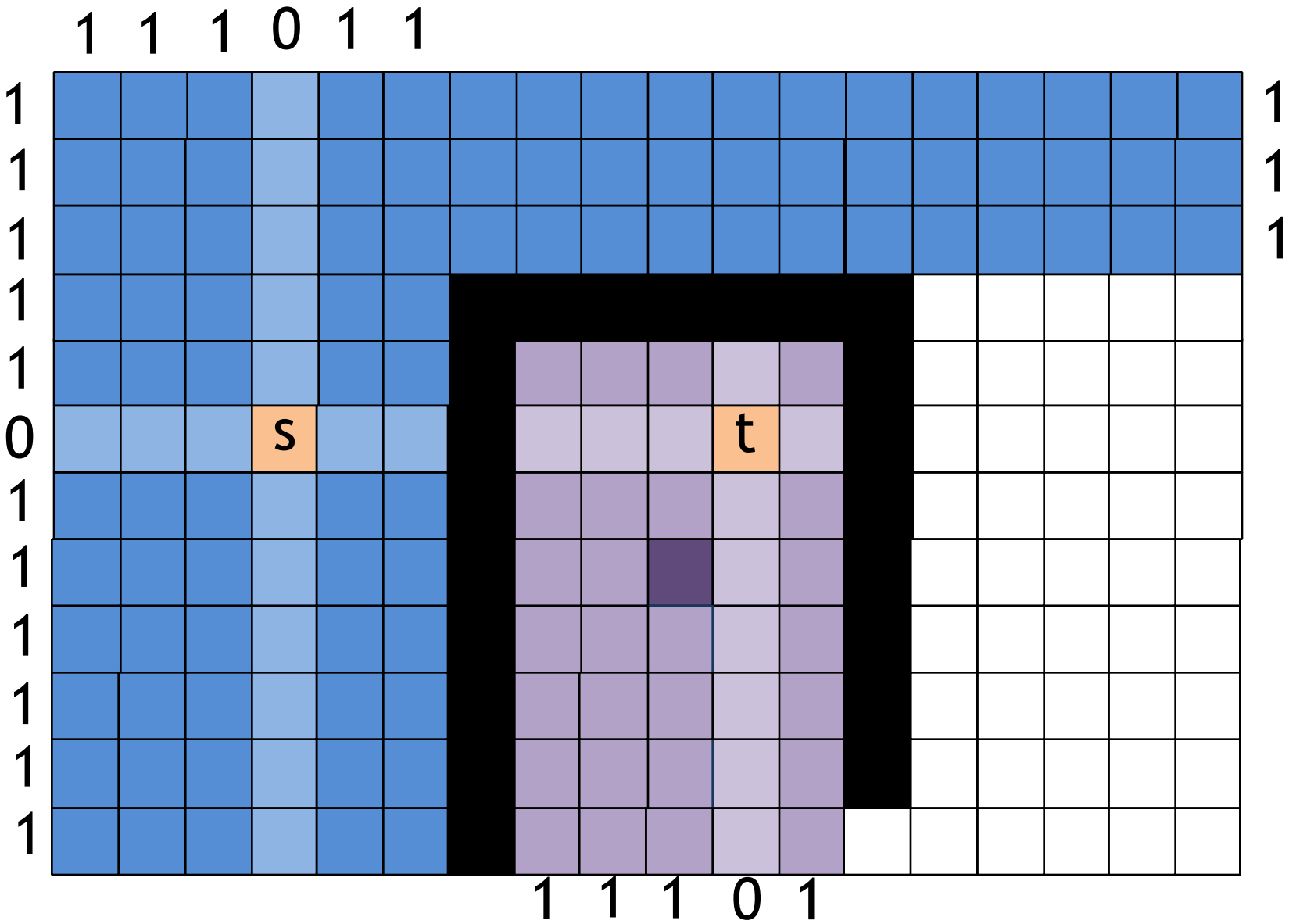
Sink Line Probe (Level 1)



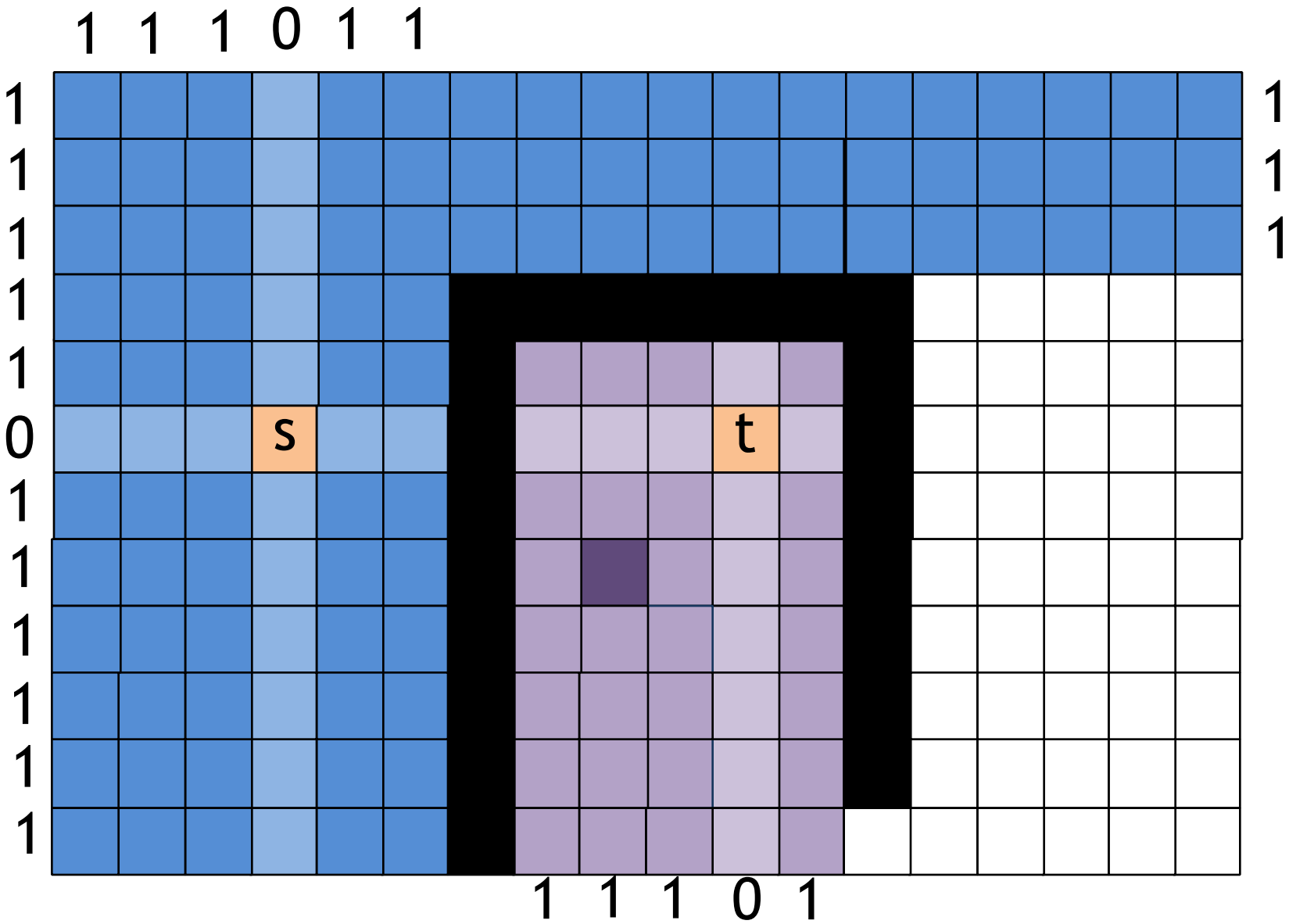
Sink Line Probe (Level 1)



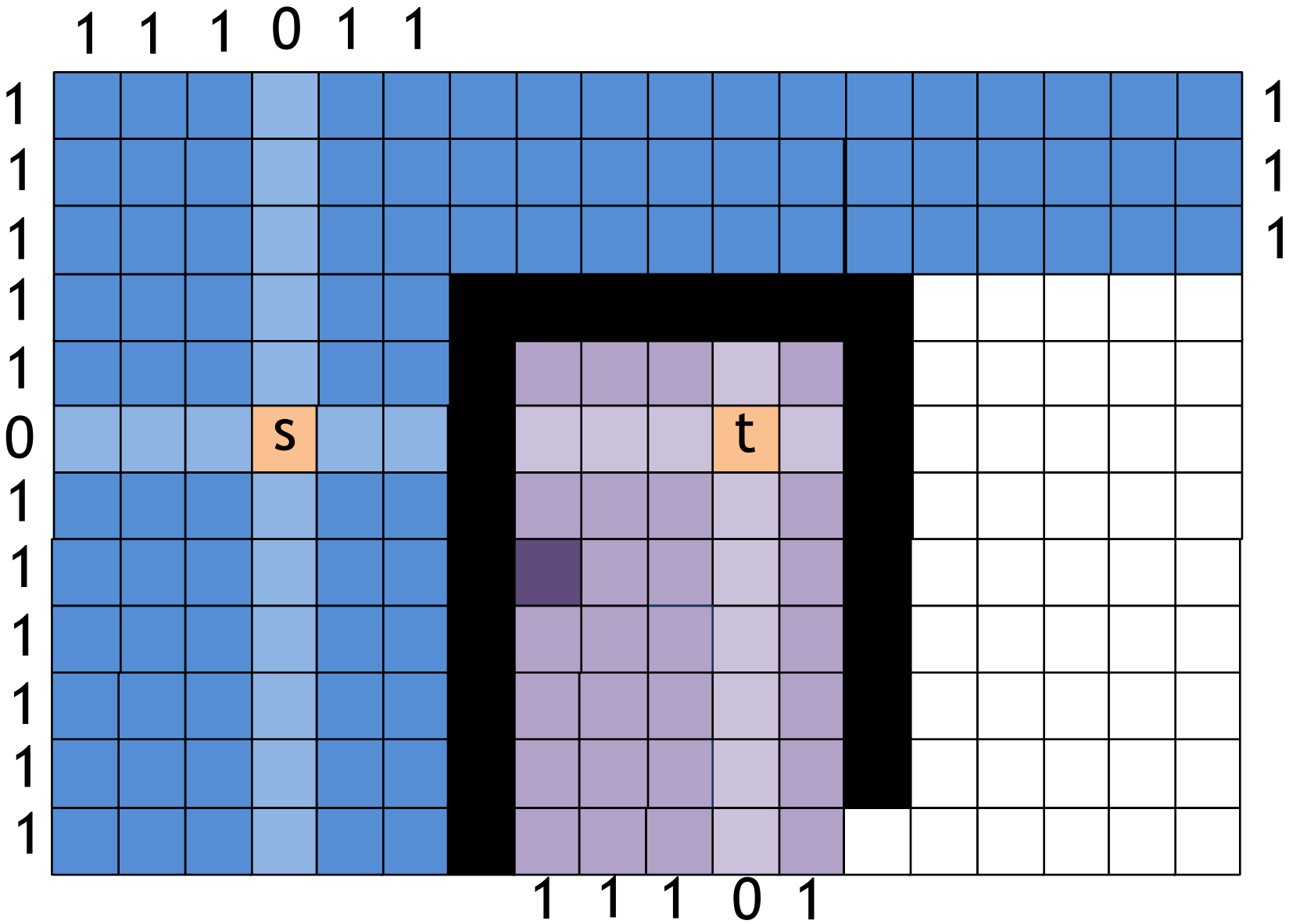
Sink Line Probe (Level 1)



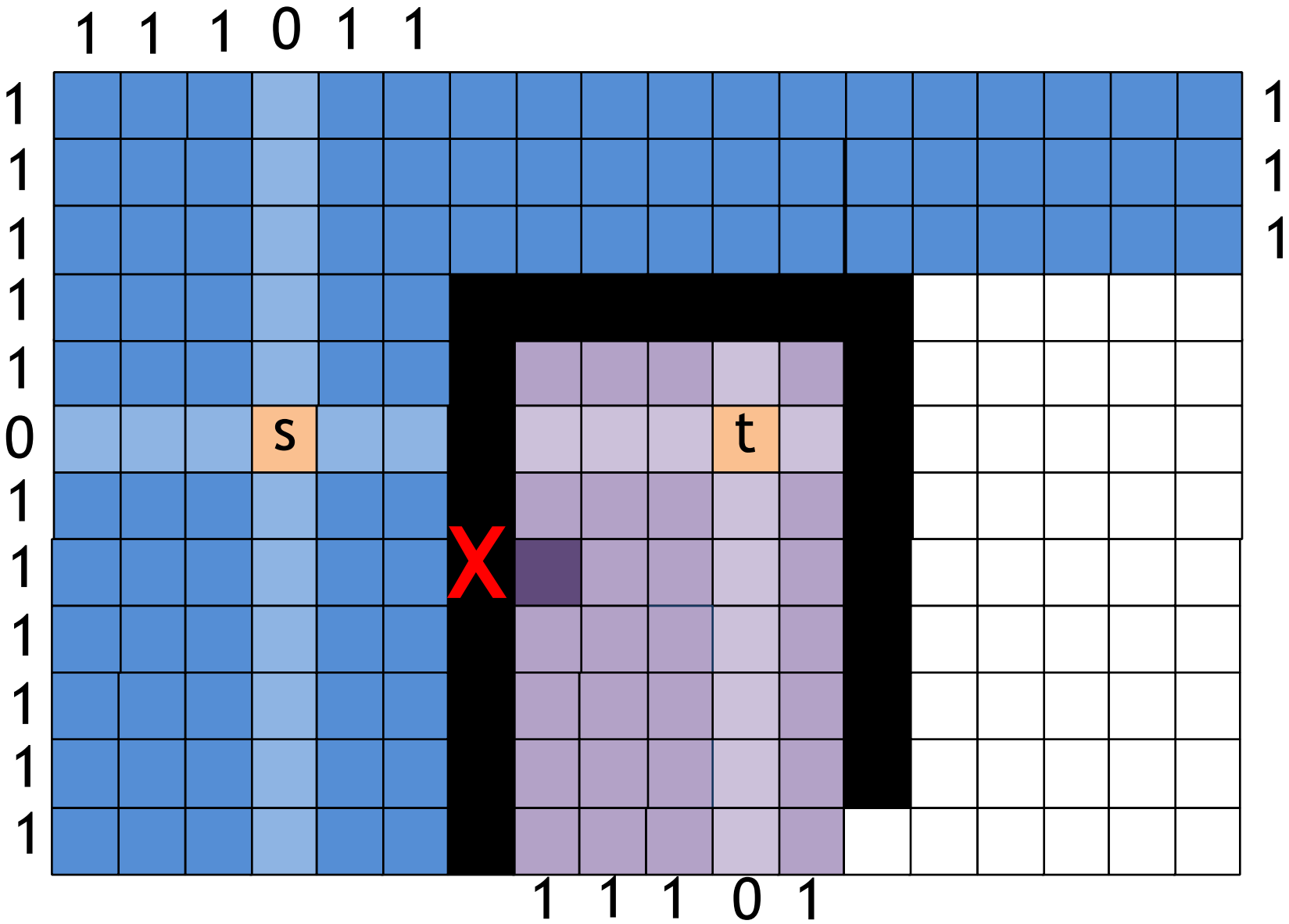
Sink Line Probe (Level 1)



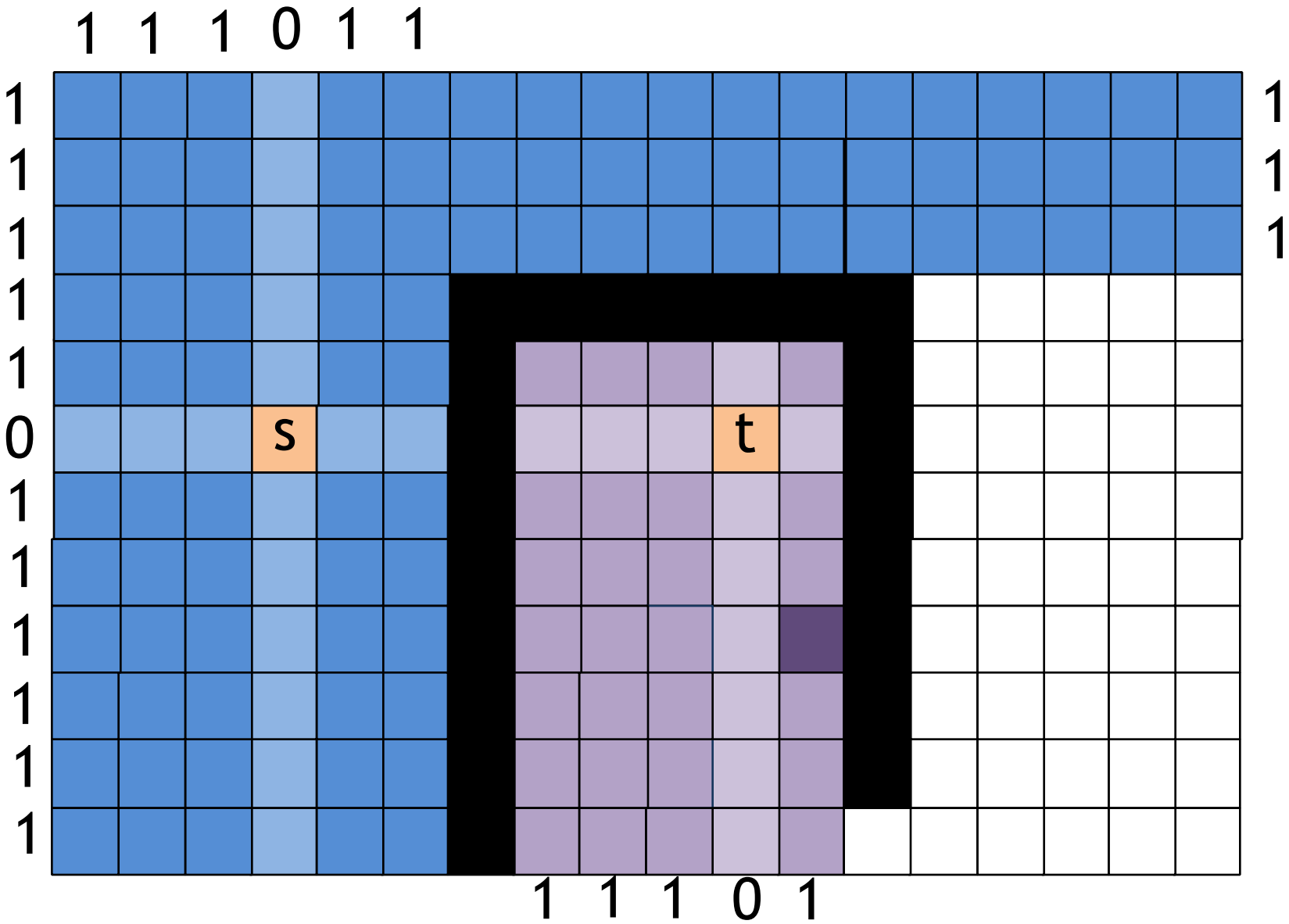
Sink Line Probe (Level 1)



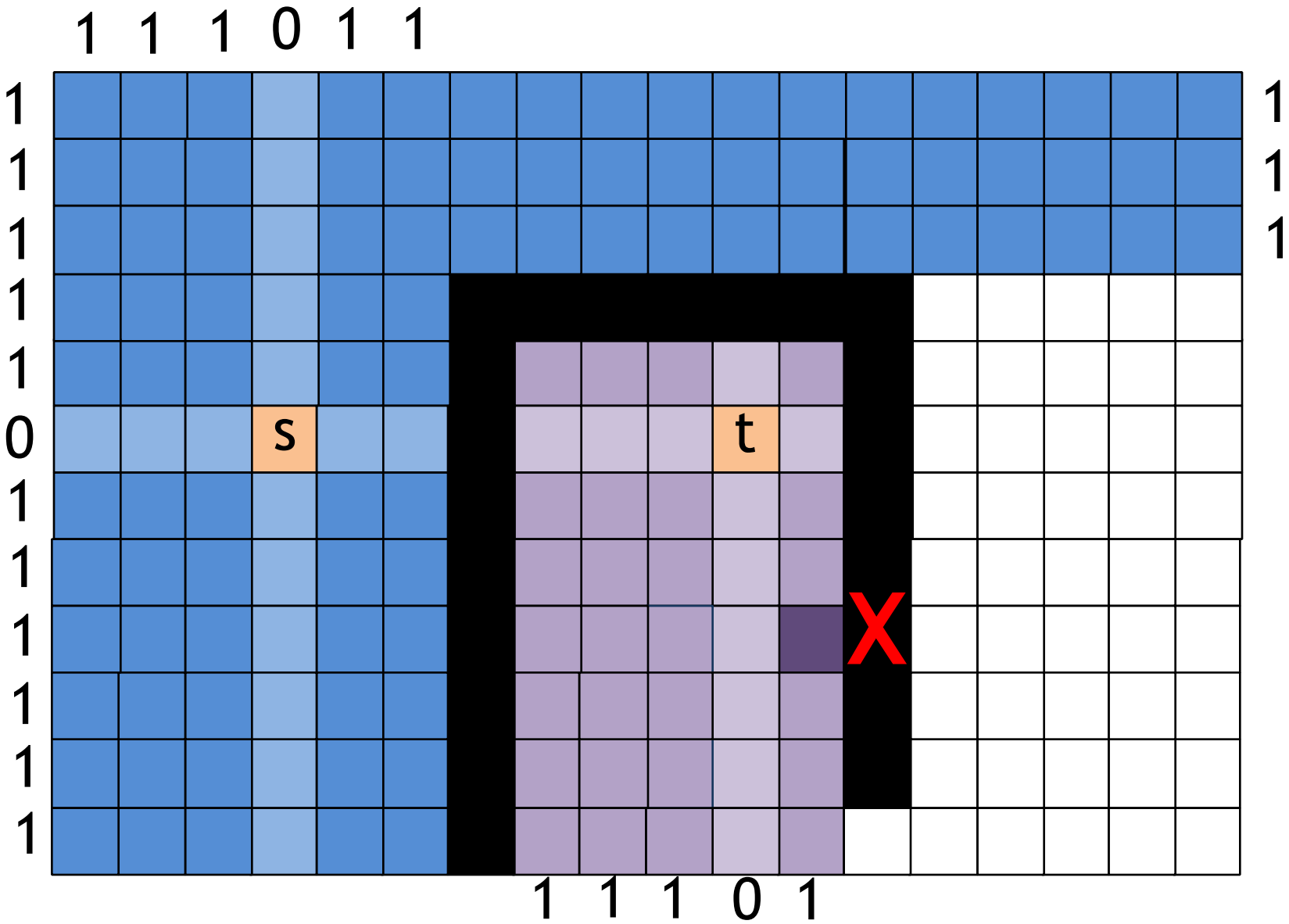
Sink Line Probe (Level 1)



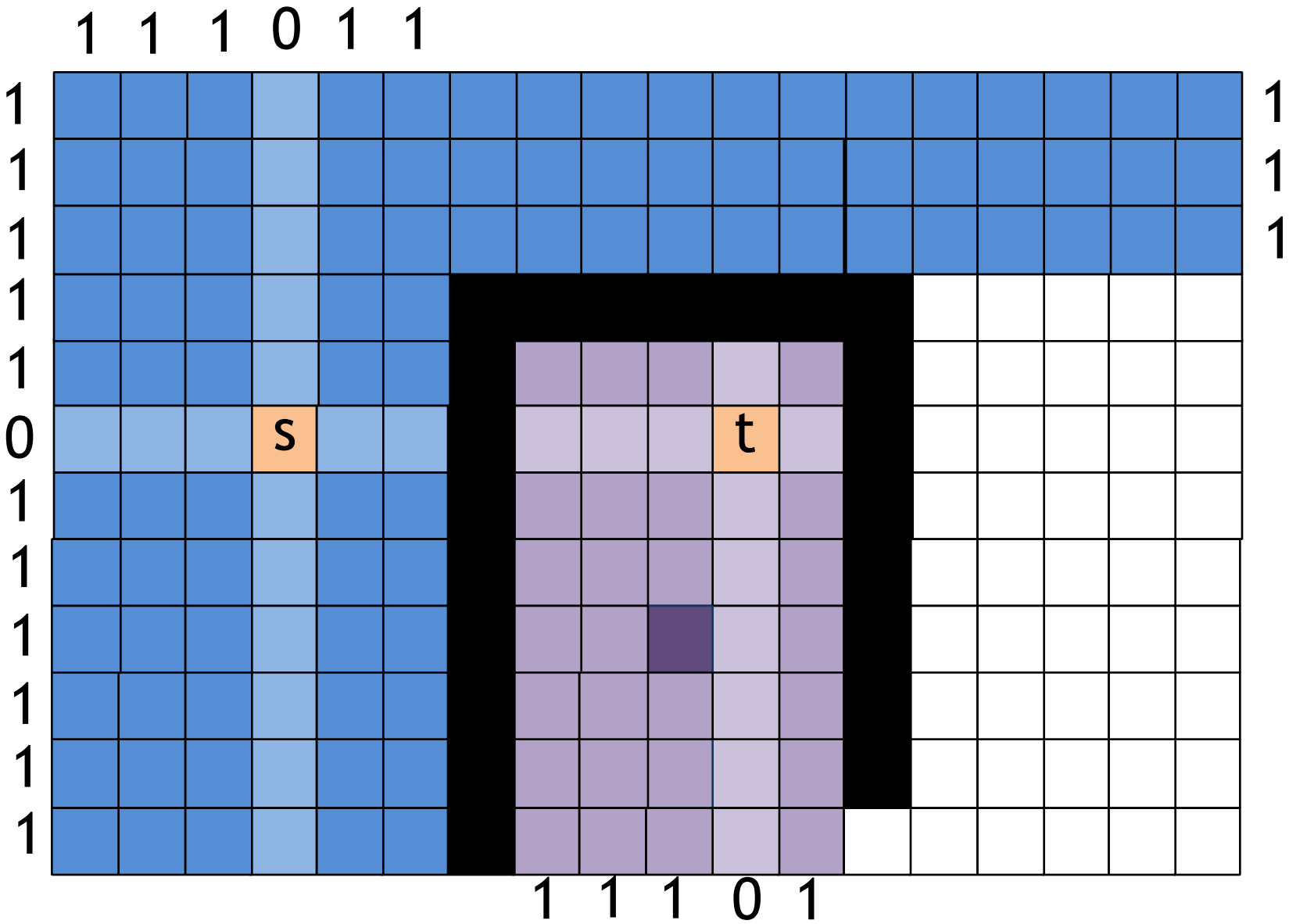
Sink Line Probe (Level 1)



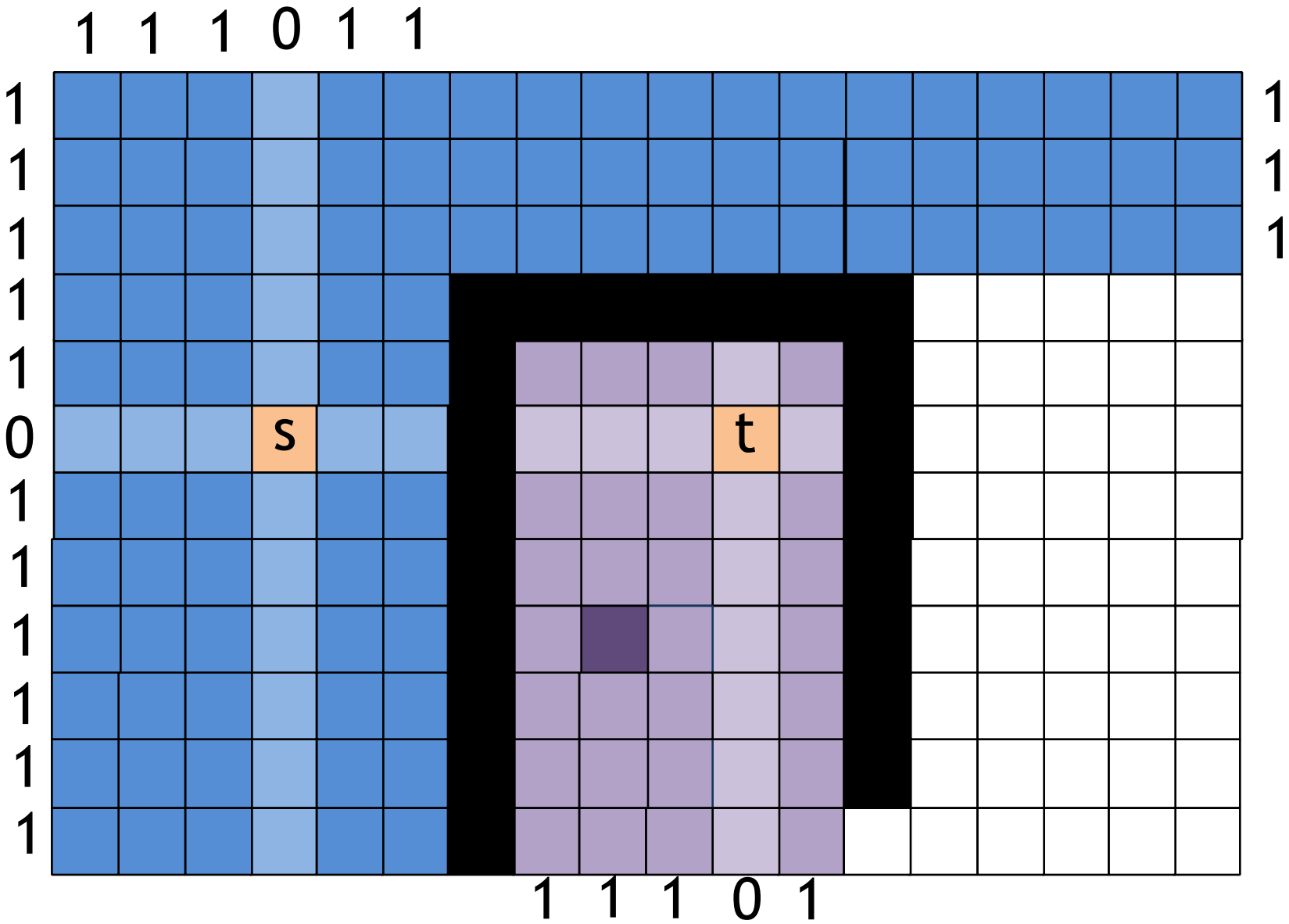
Sink Line Probe (Level 1)



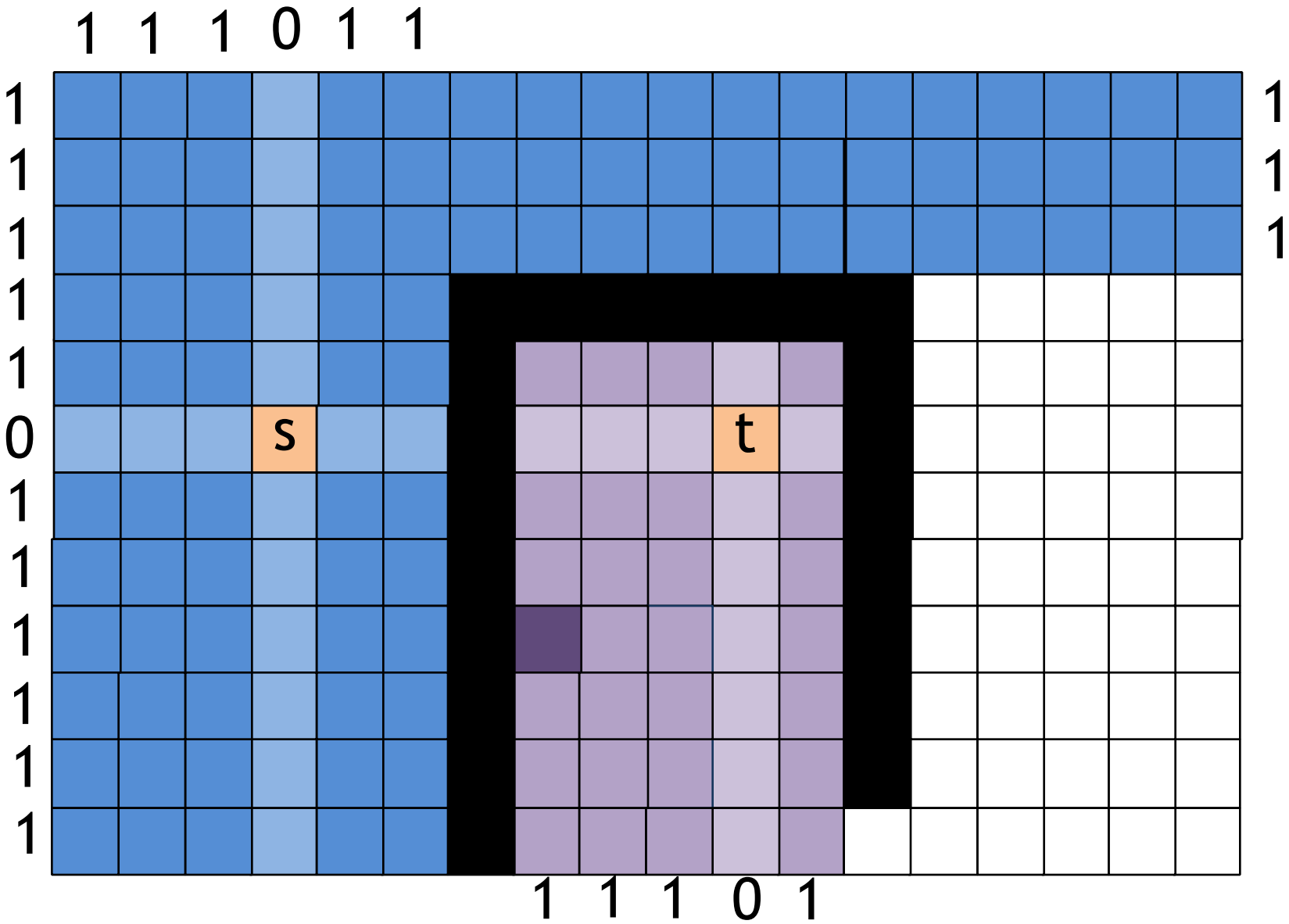
Sink Line Probe (Level 1)



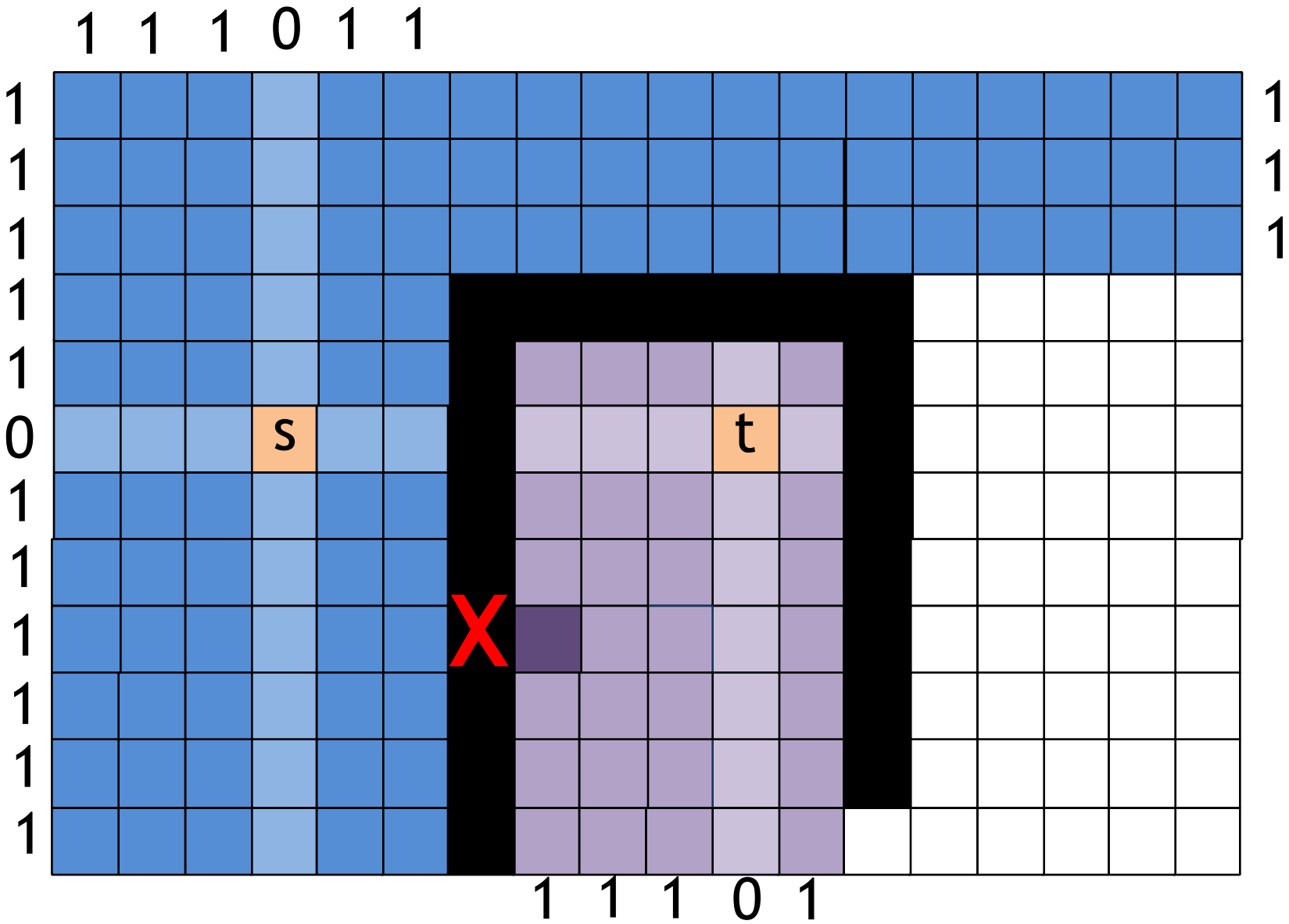
Sink Line Probe (Level 1)



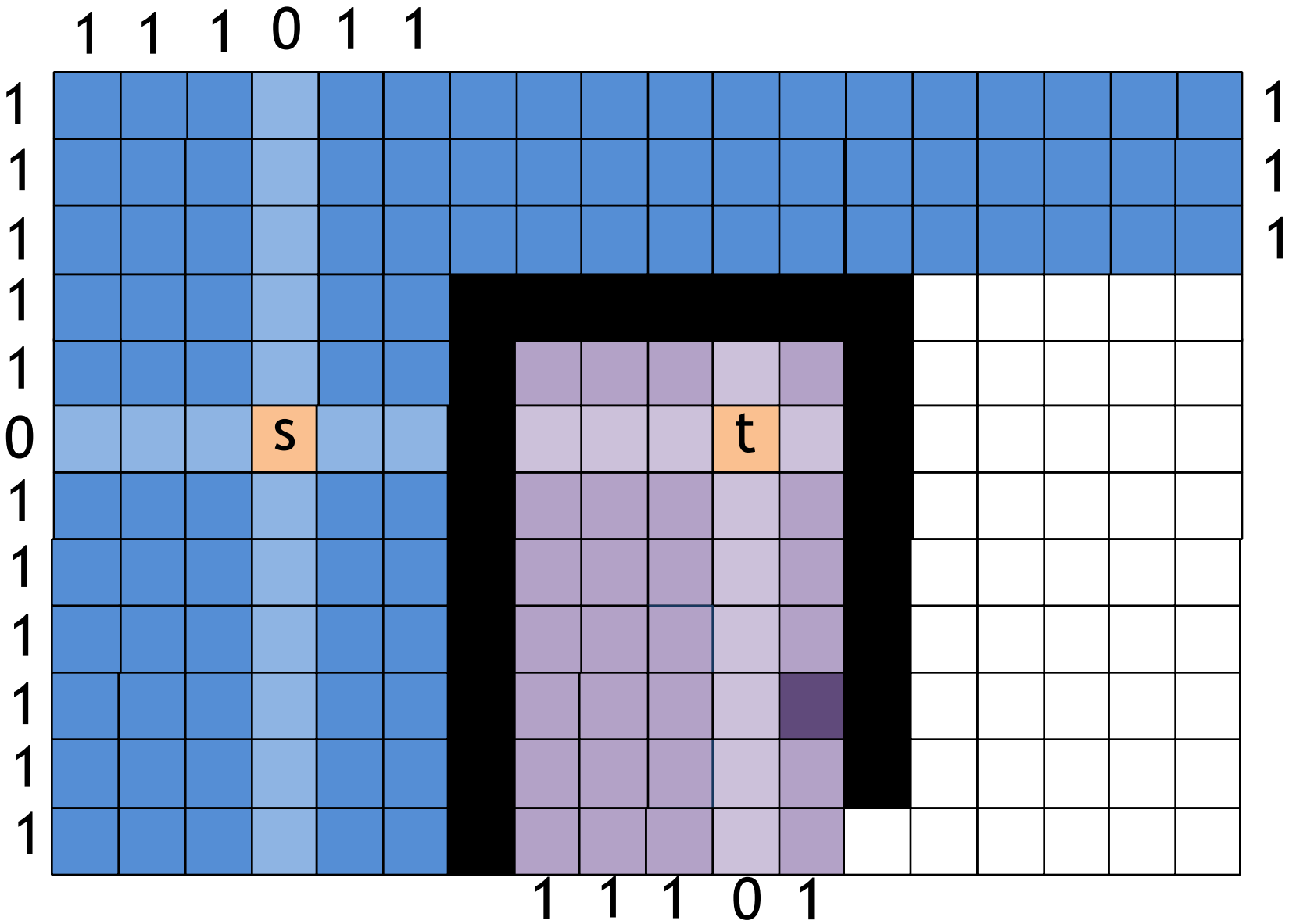
Sink Line Probe (Level 1)



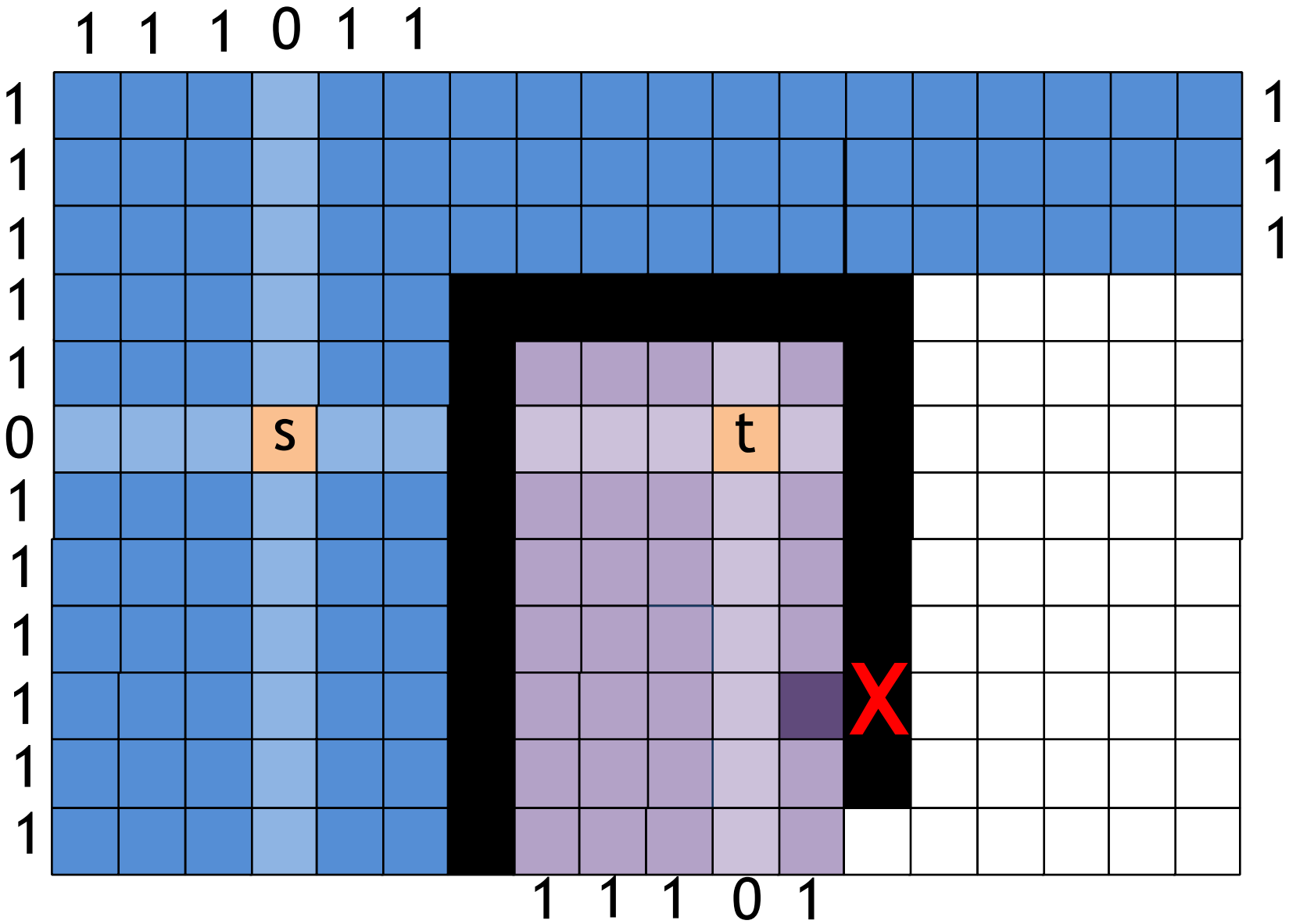
Sink Line Probe (Level 1)



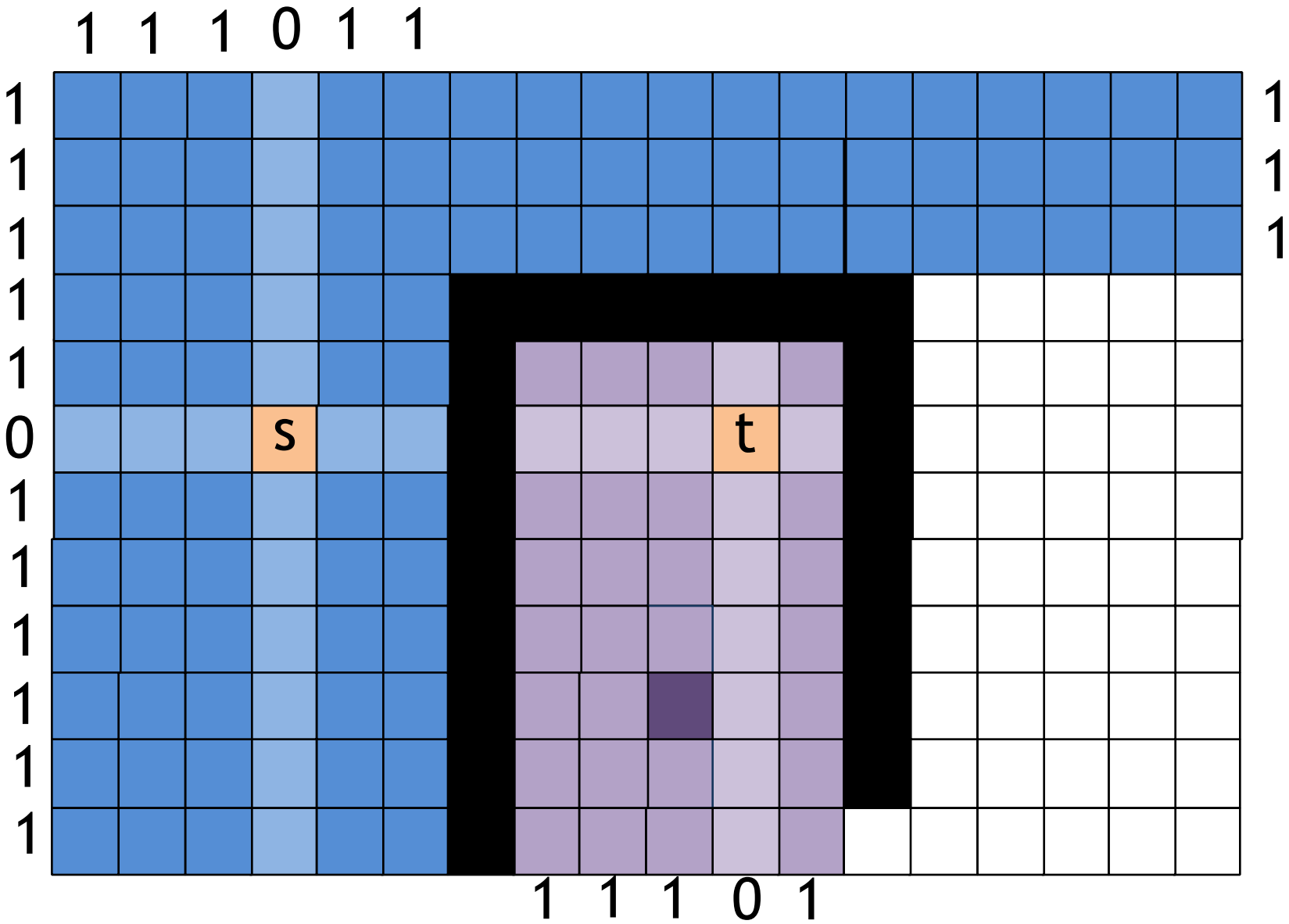
Sink Line Probe (Level 1)



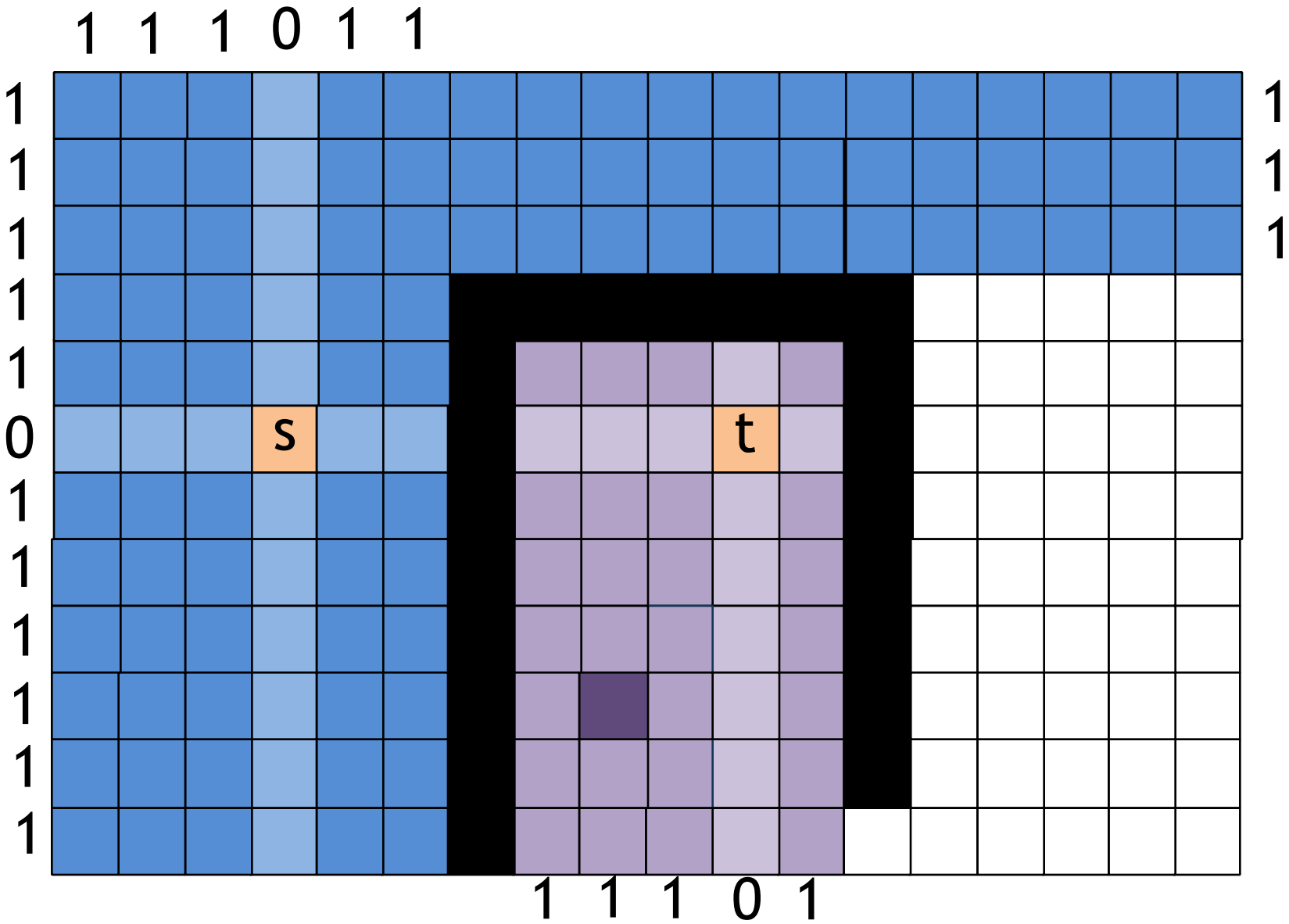
Sink Line Probe (Level 1)



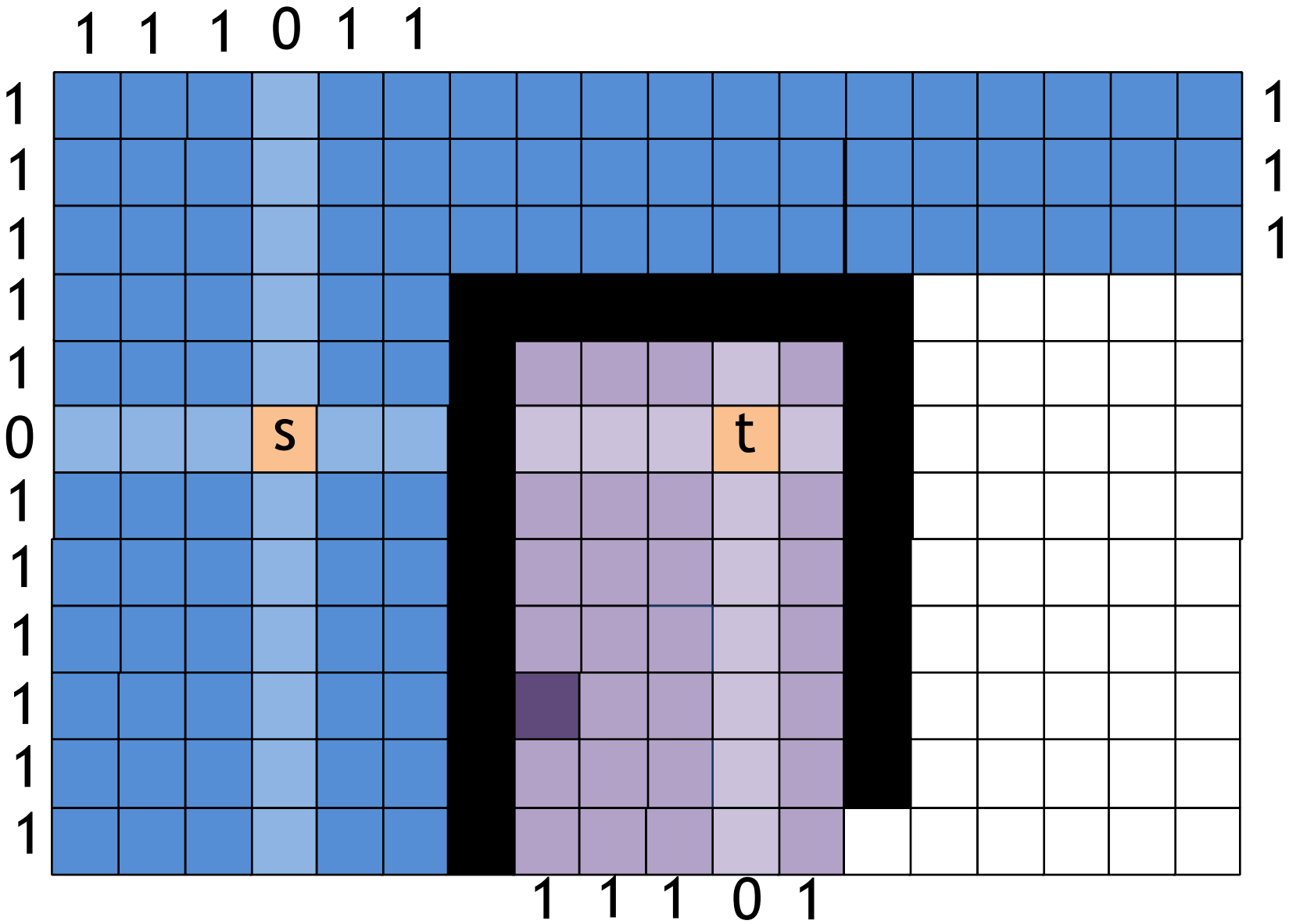
Sink Line Probe (Level 1)



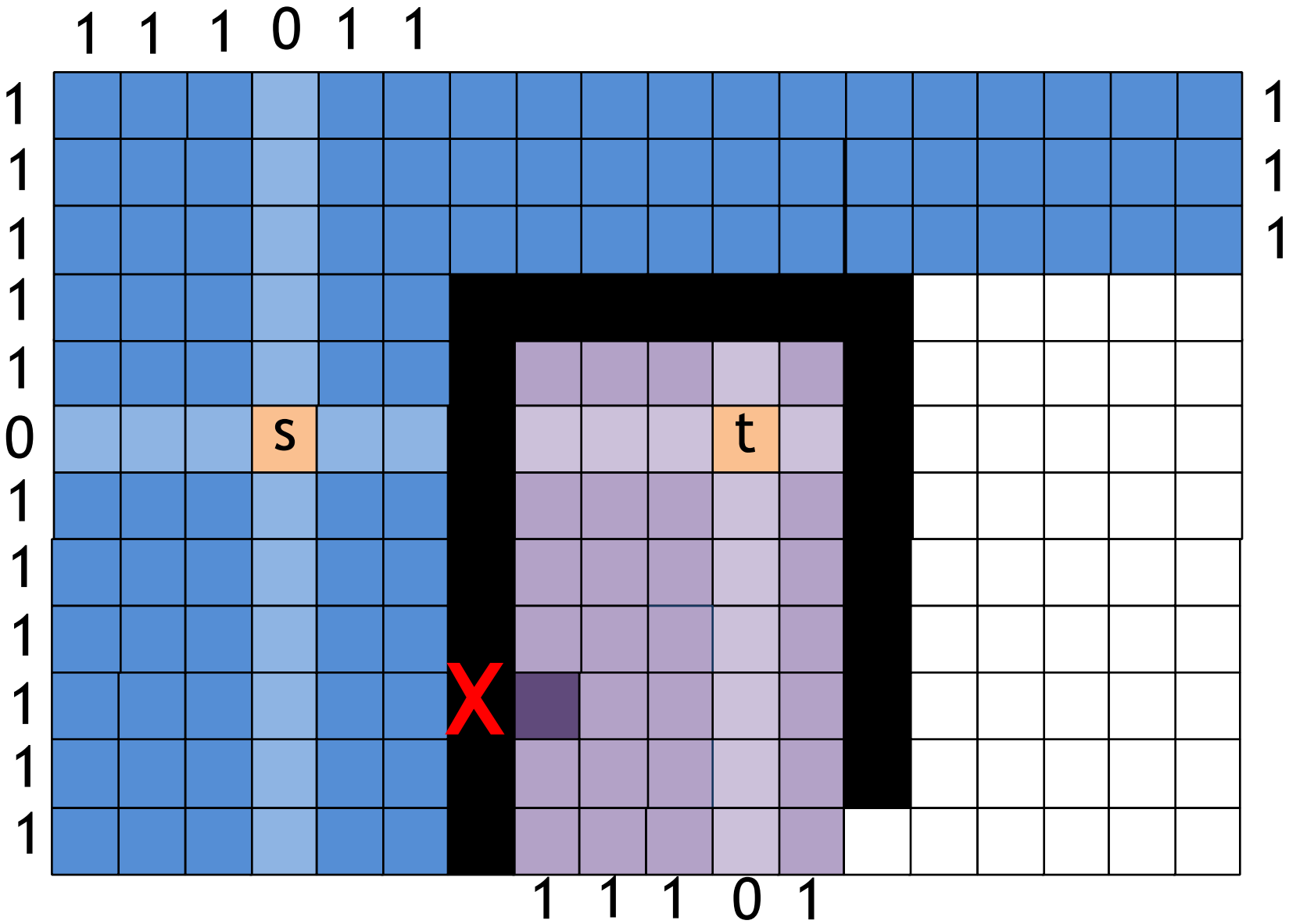
Sink Line Probe (Level 1)



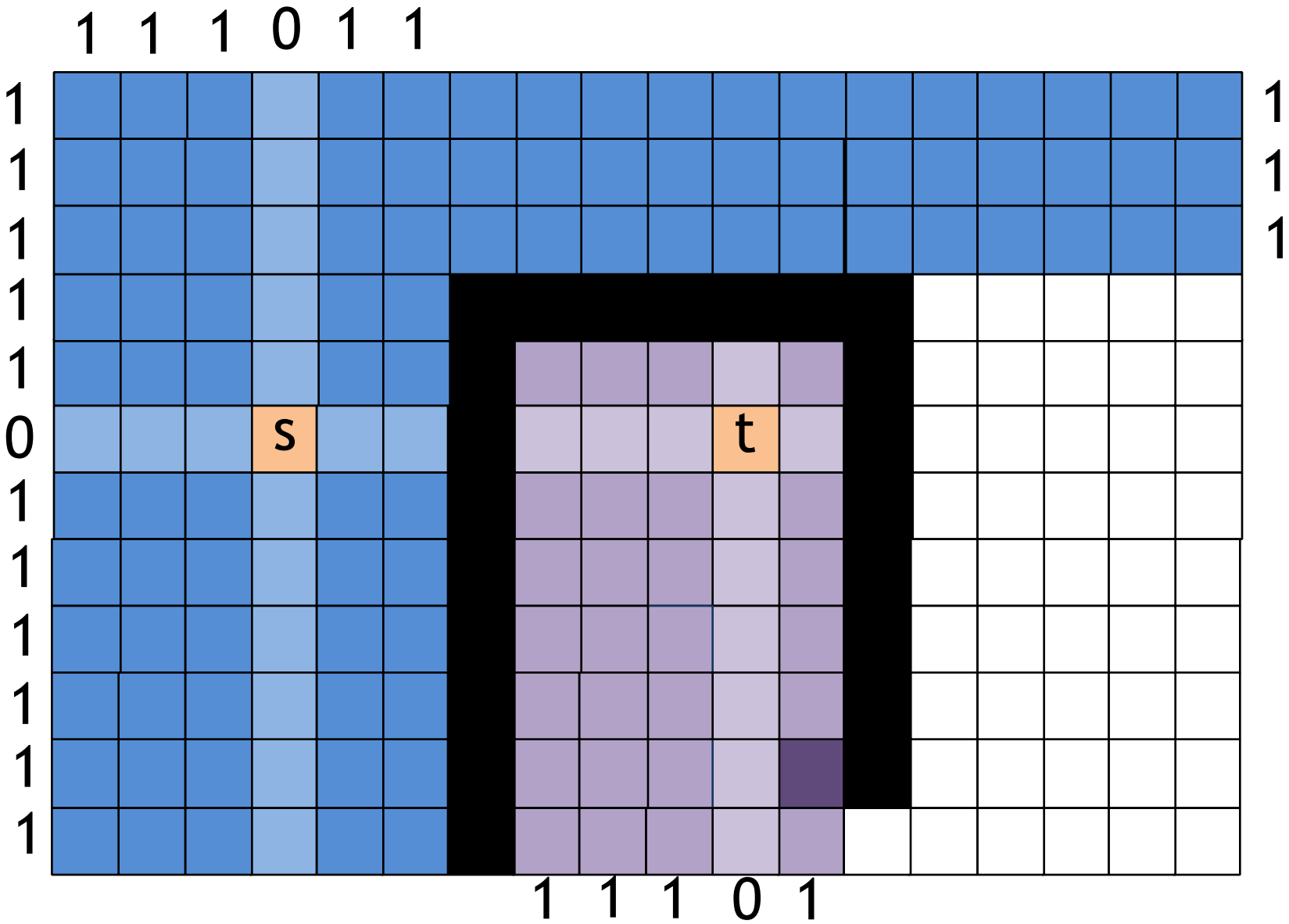
Sink Line Probe (Level 1)



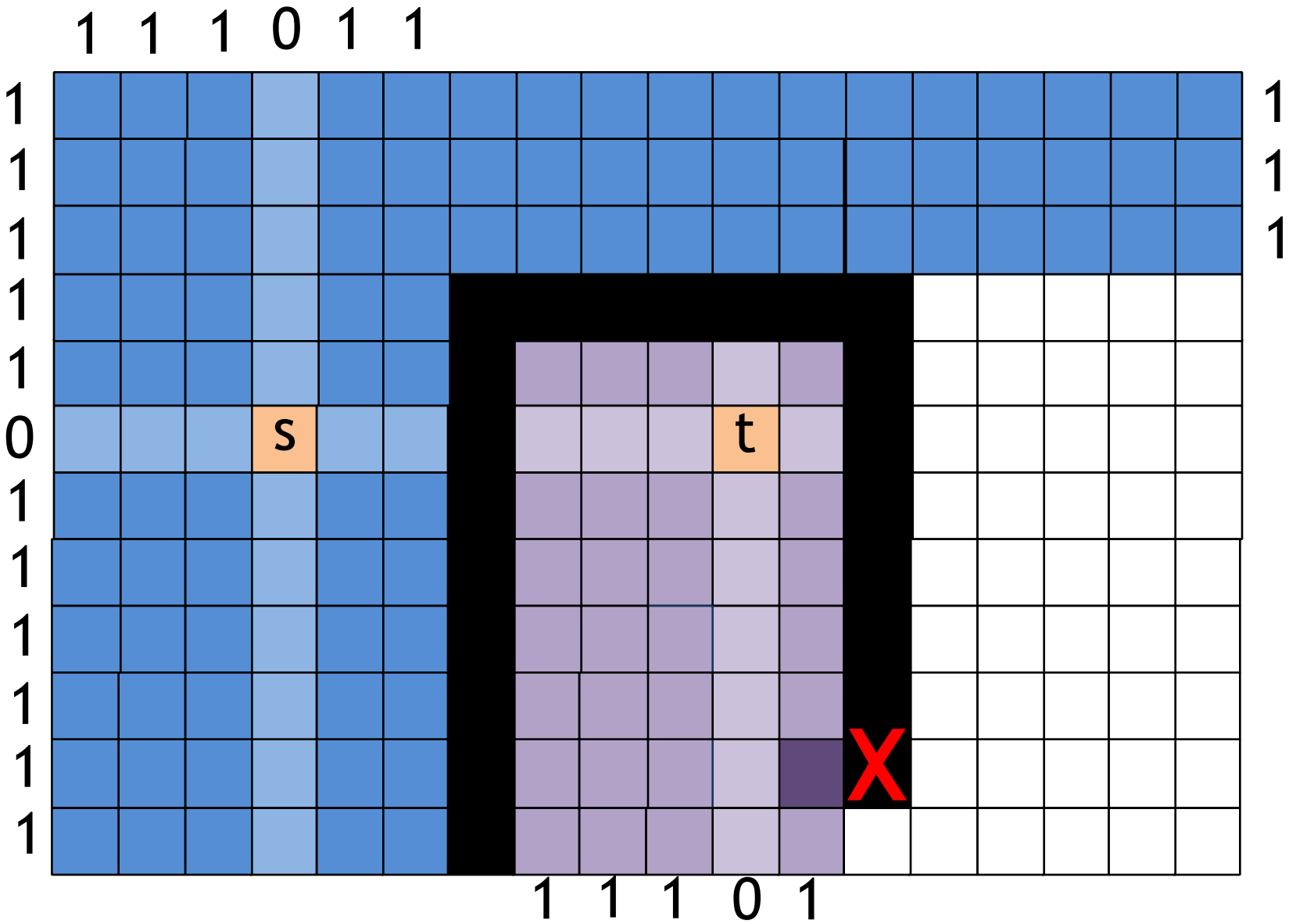
Sink Line Probe (Level 1)



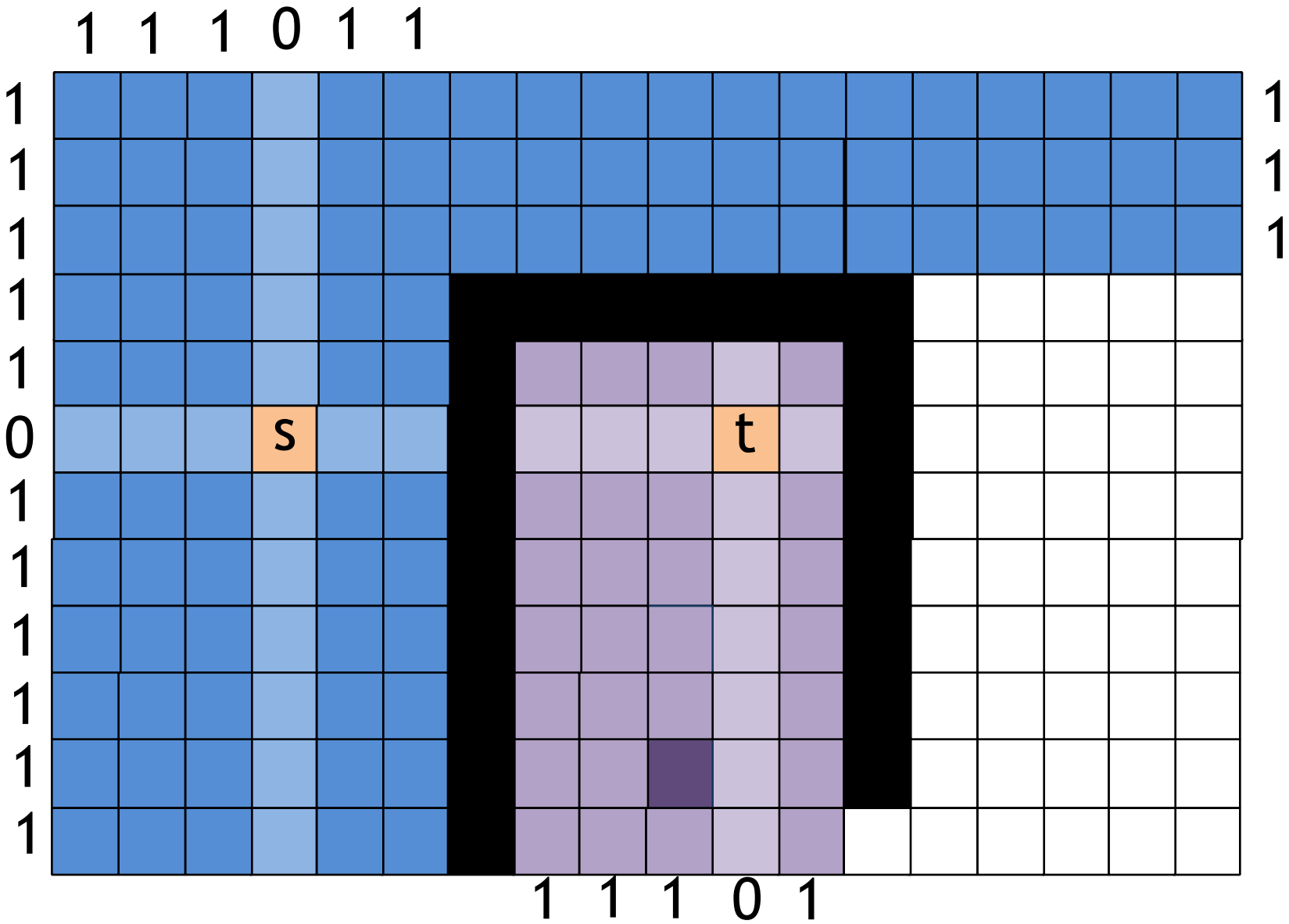
Sink Line Probe (Level 1)



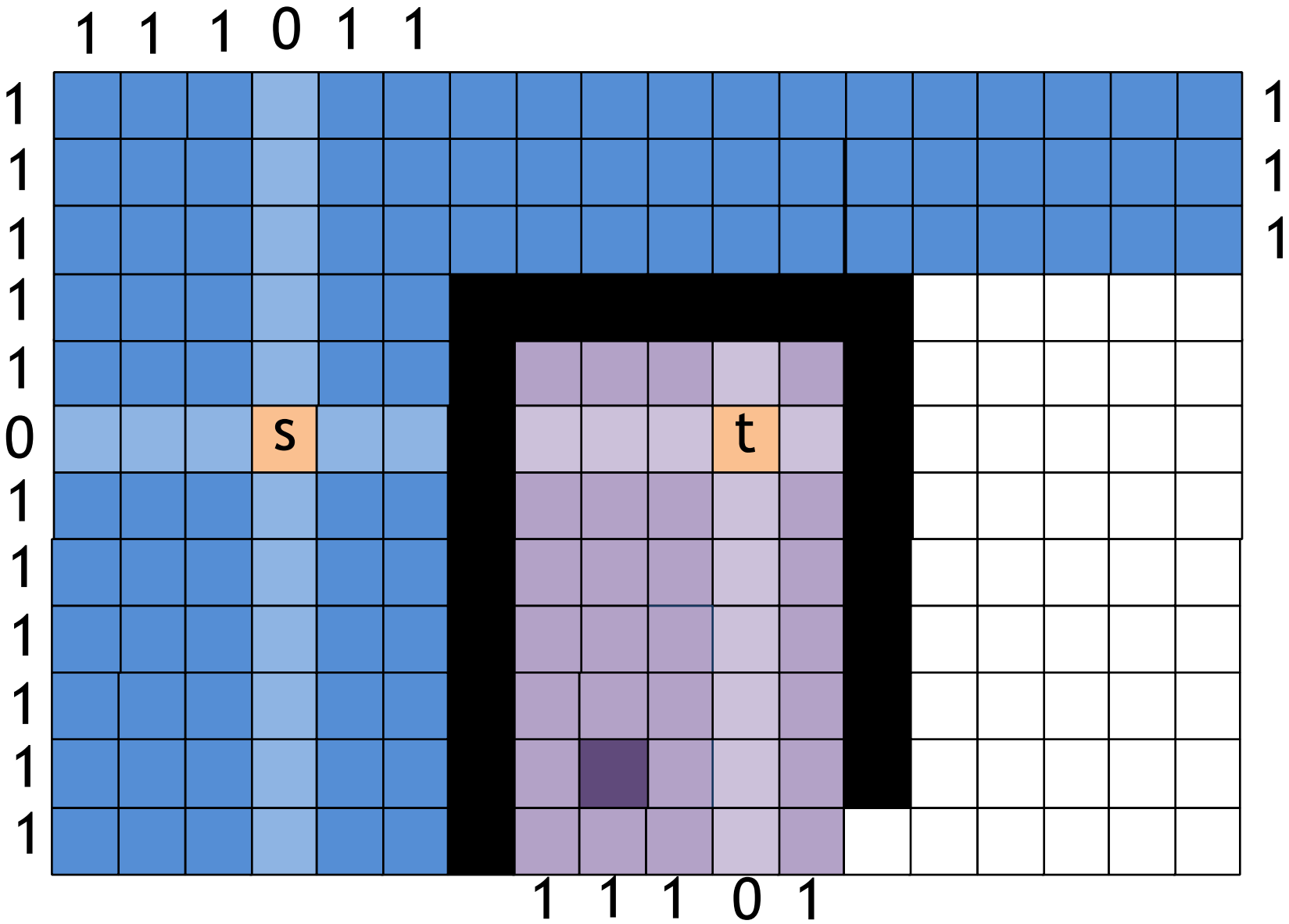
Sink Line Probe (Level 1)



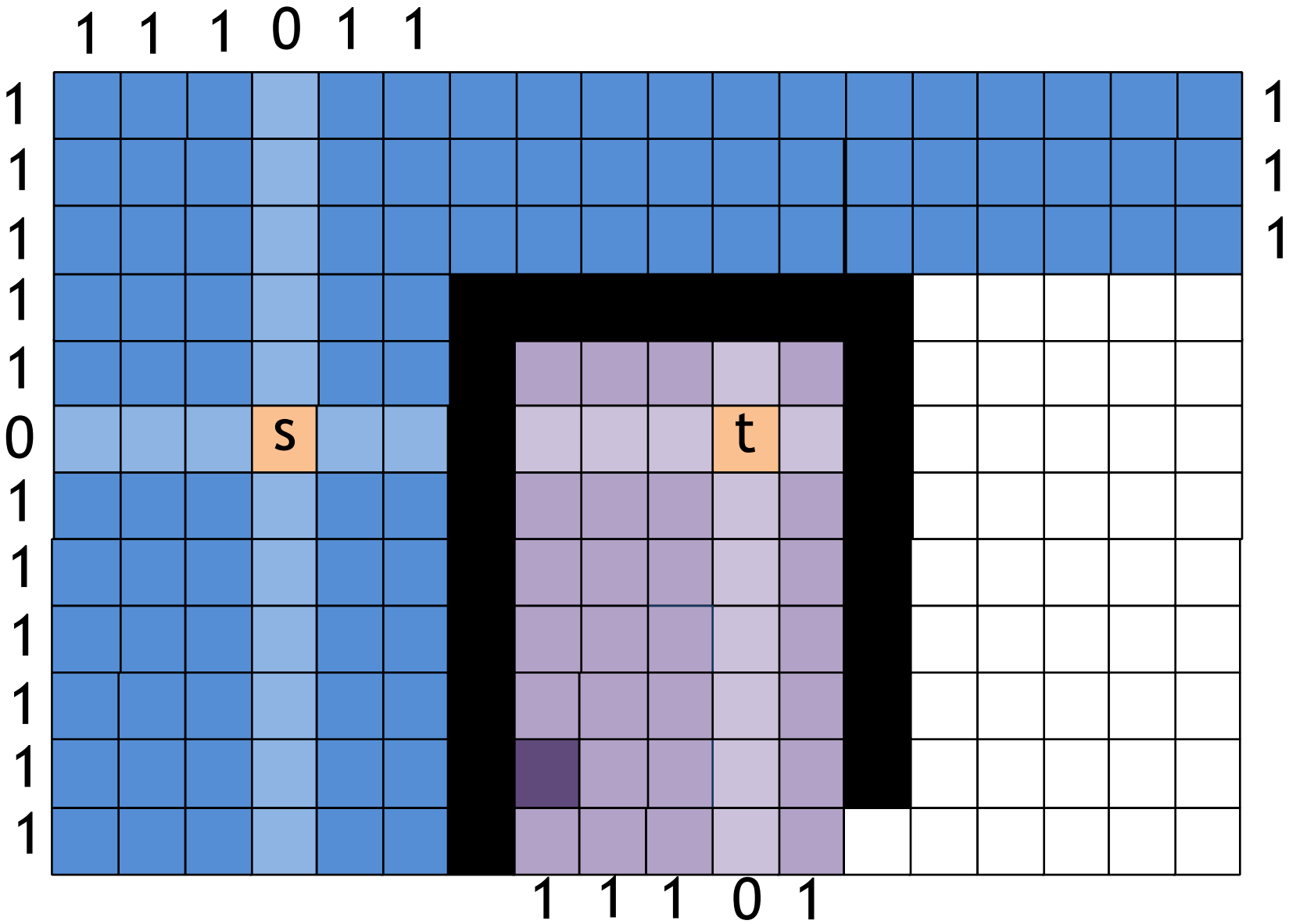
Sink Line Probe (Level 1)



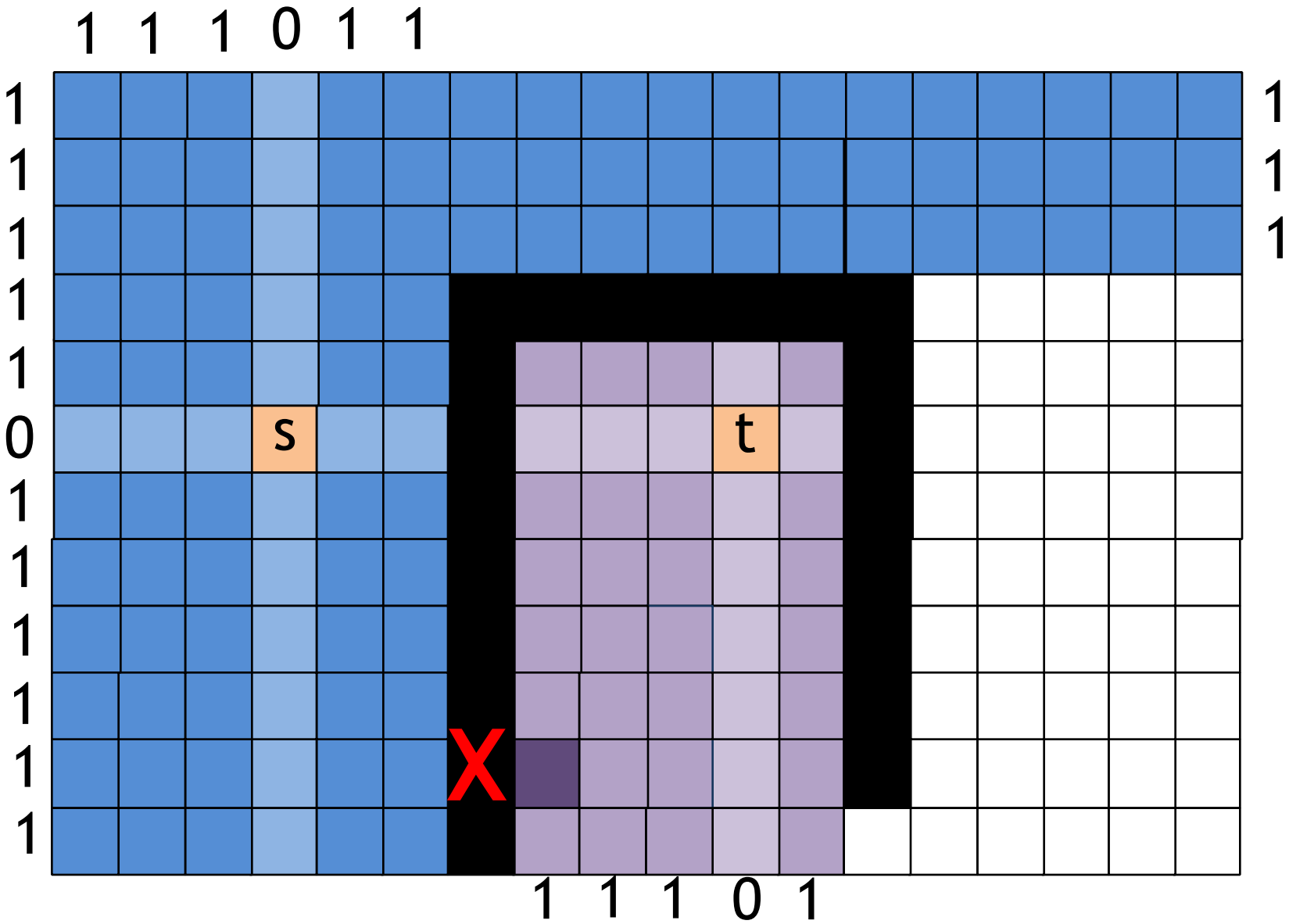
Sink Line Probe (Level 1)



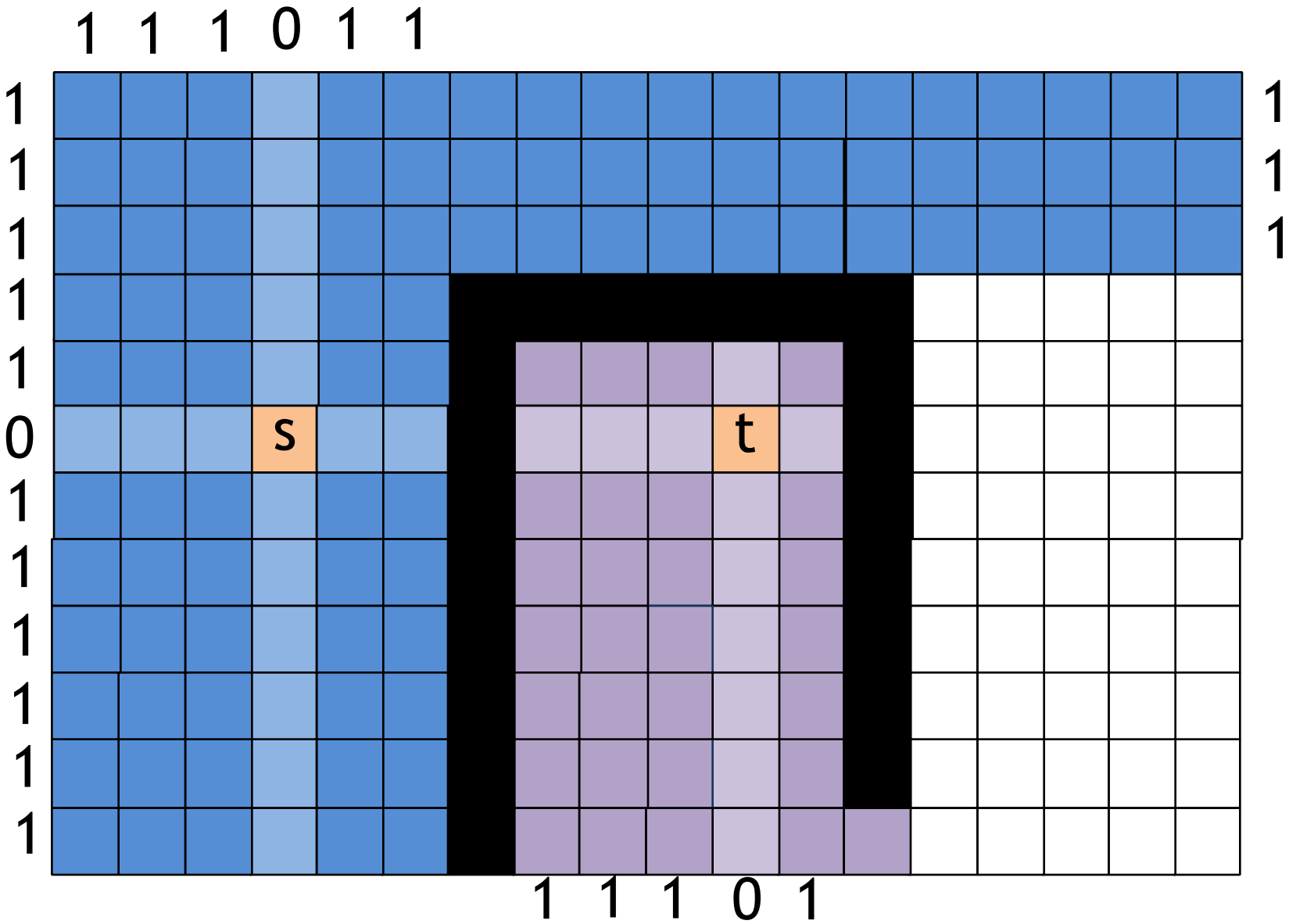
Sink Line Probe (Level 1)



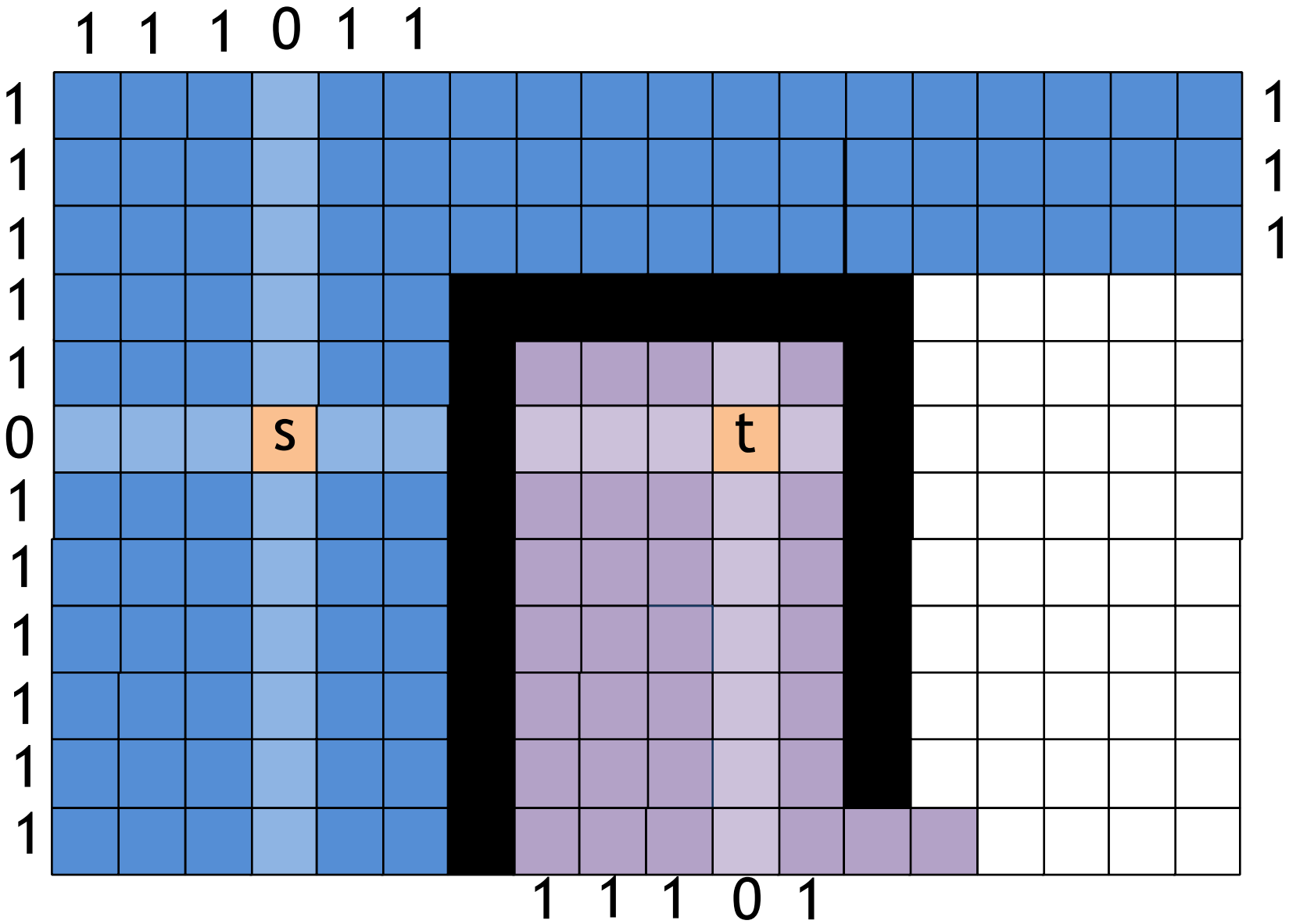
Sink Line Probe (Level 1)



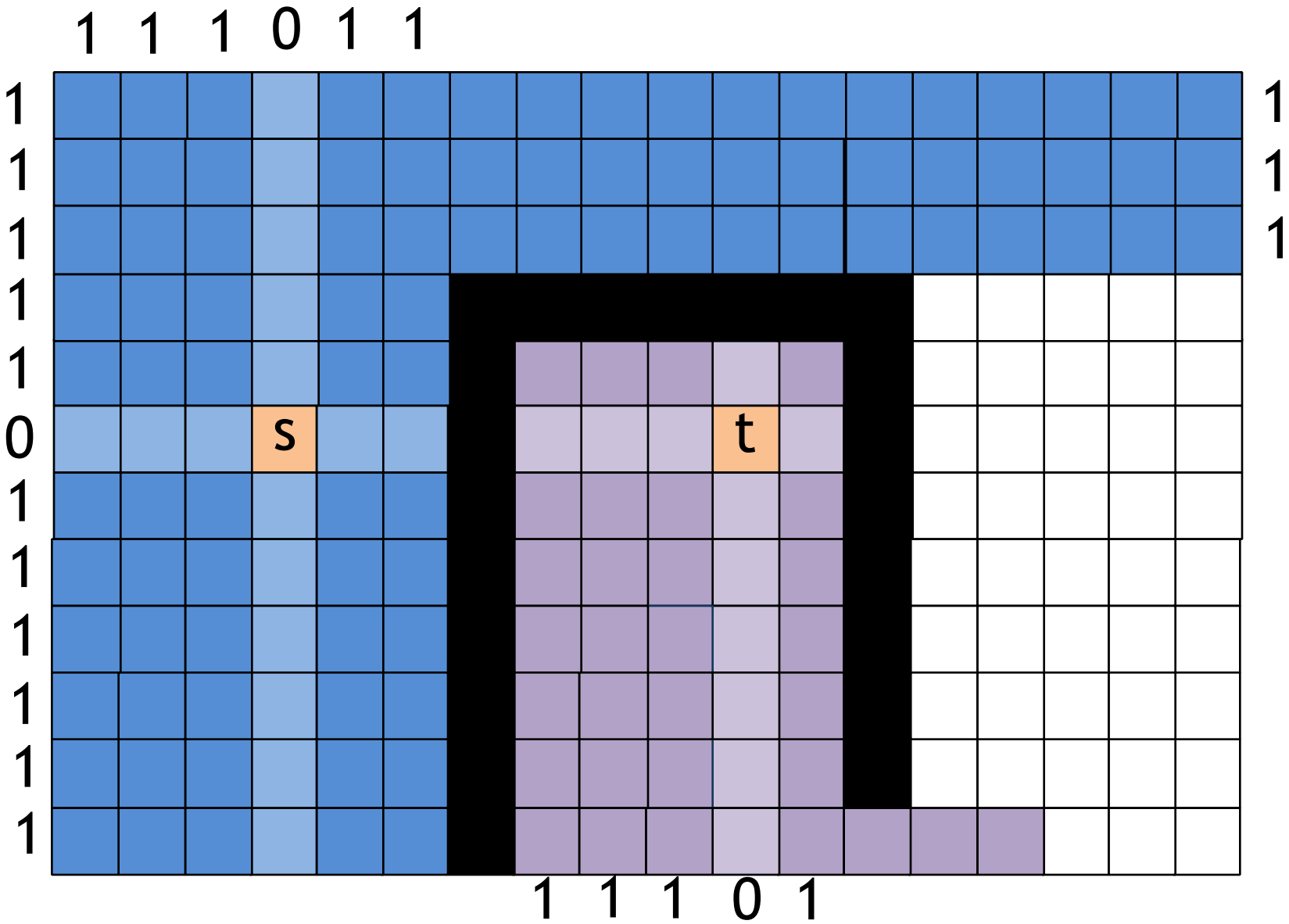
Sink Line Probe (Level 1)



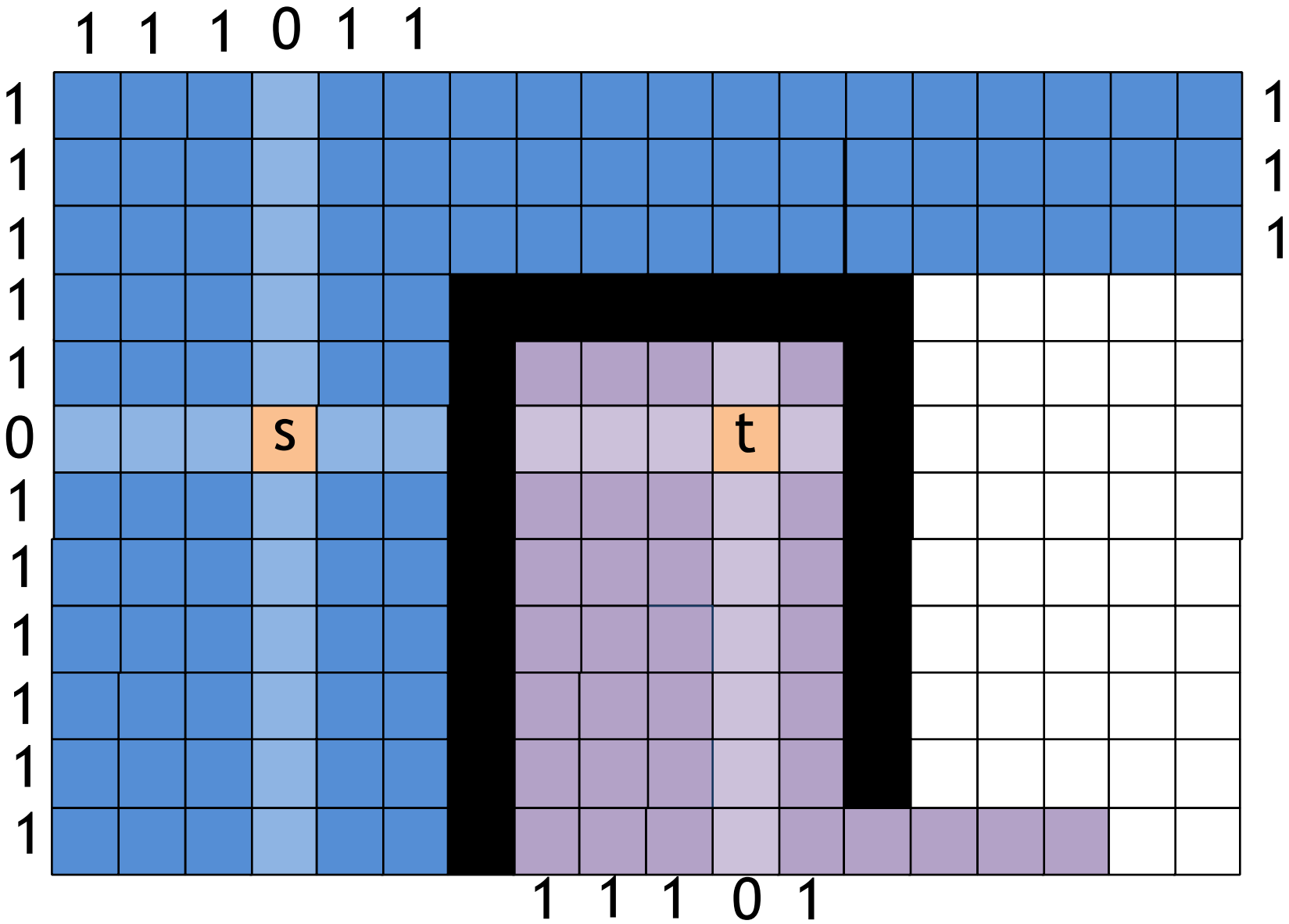
Sink Line Probe (Level 1)



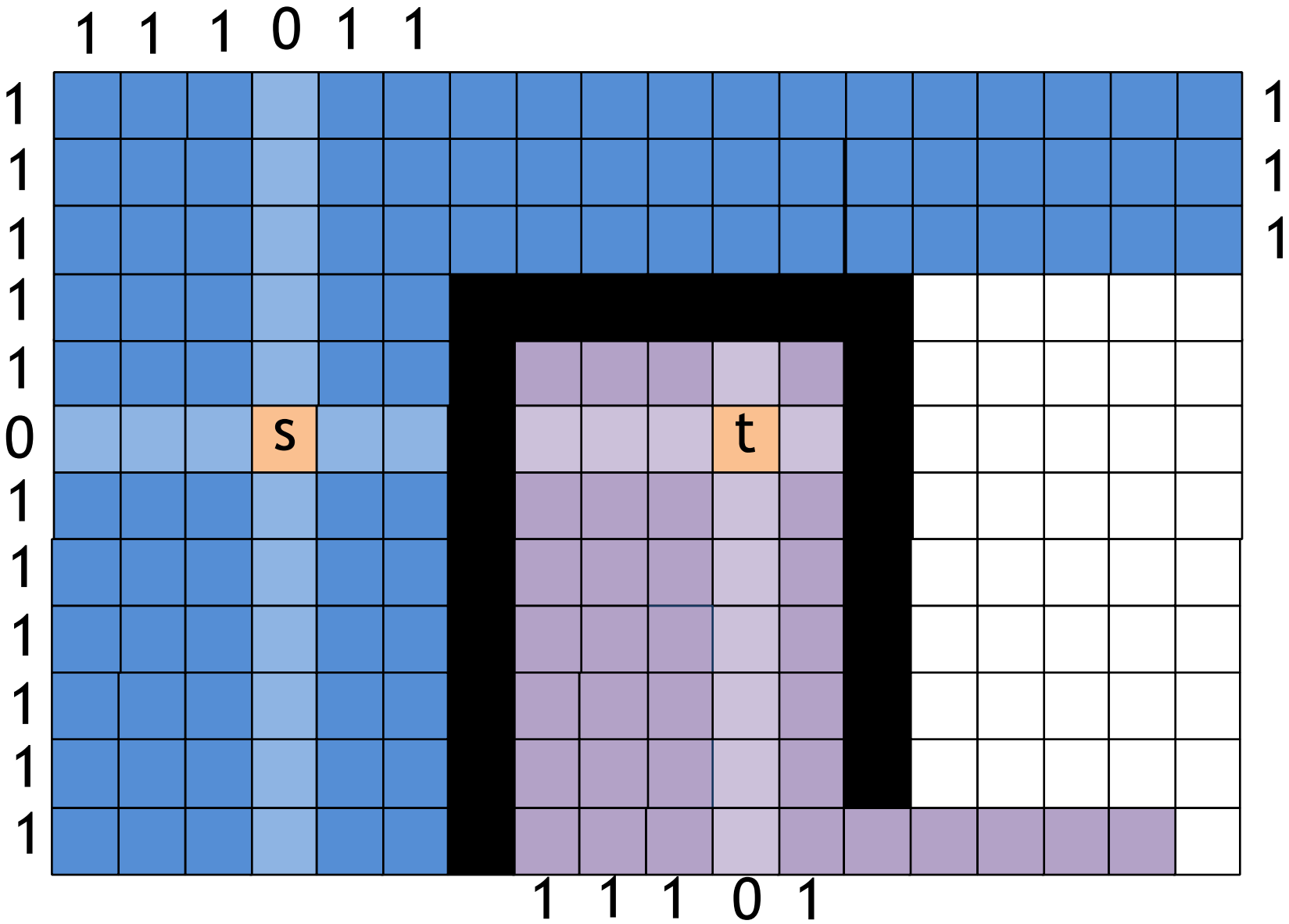
Sink Line Probe (Level 1)



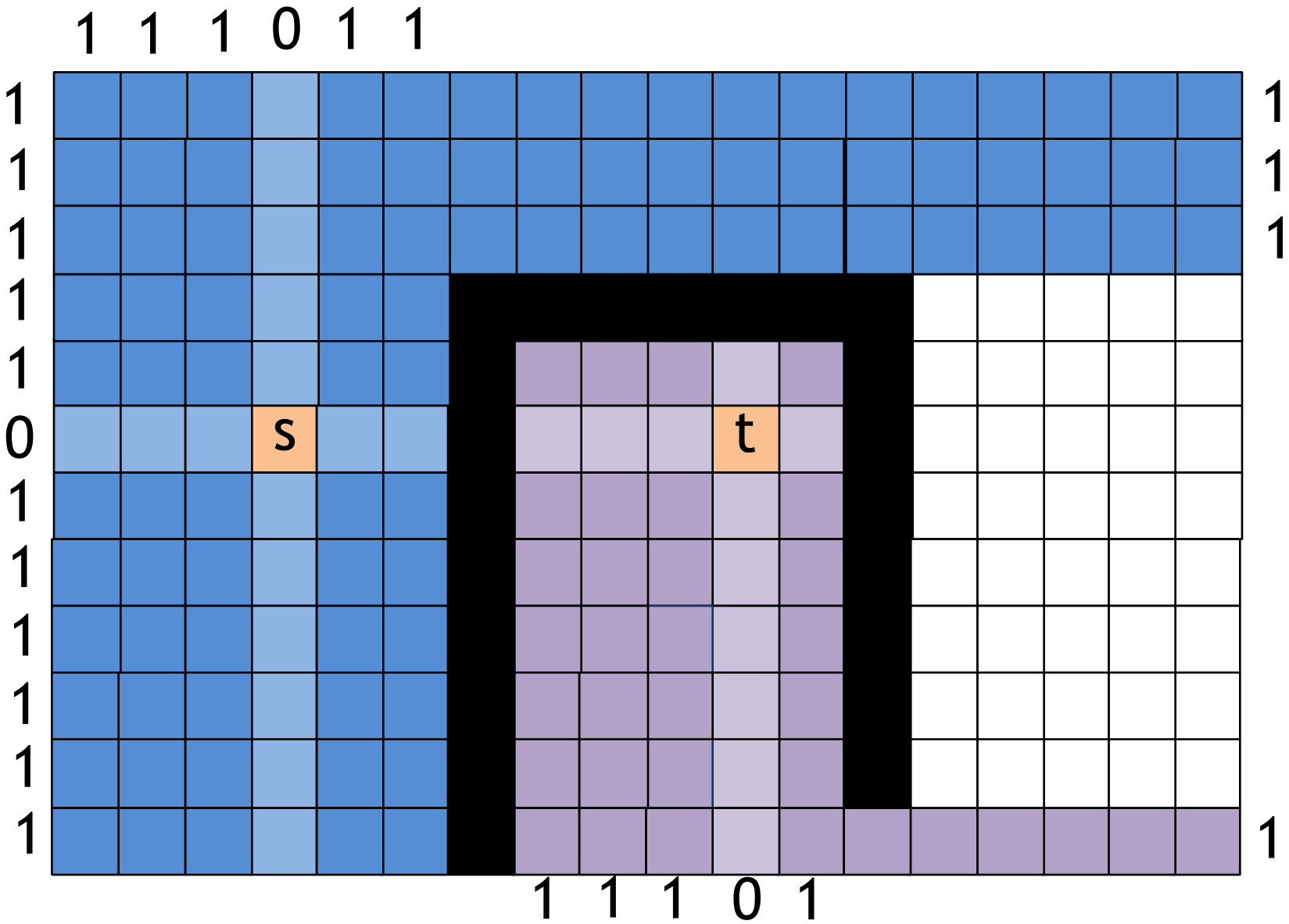
Sink Line Probe (Level 1)



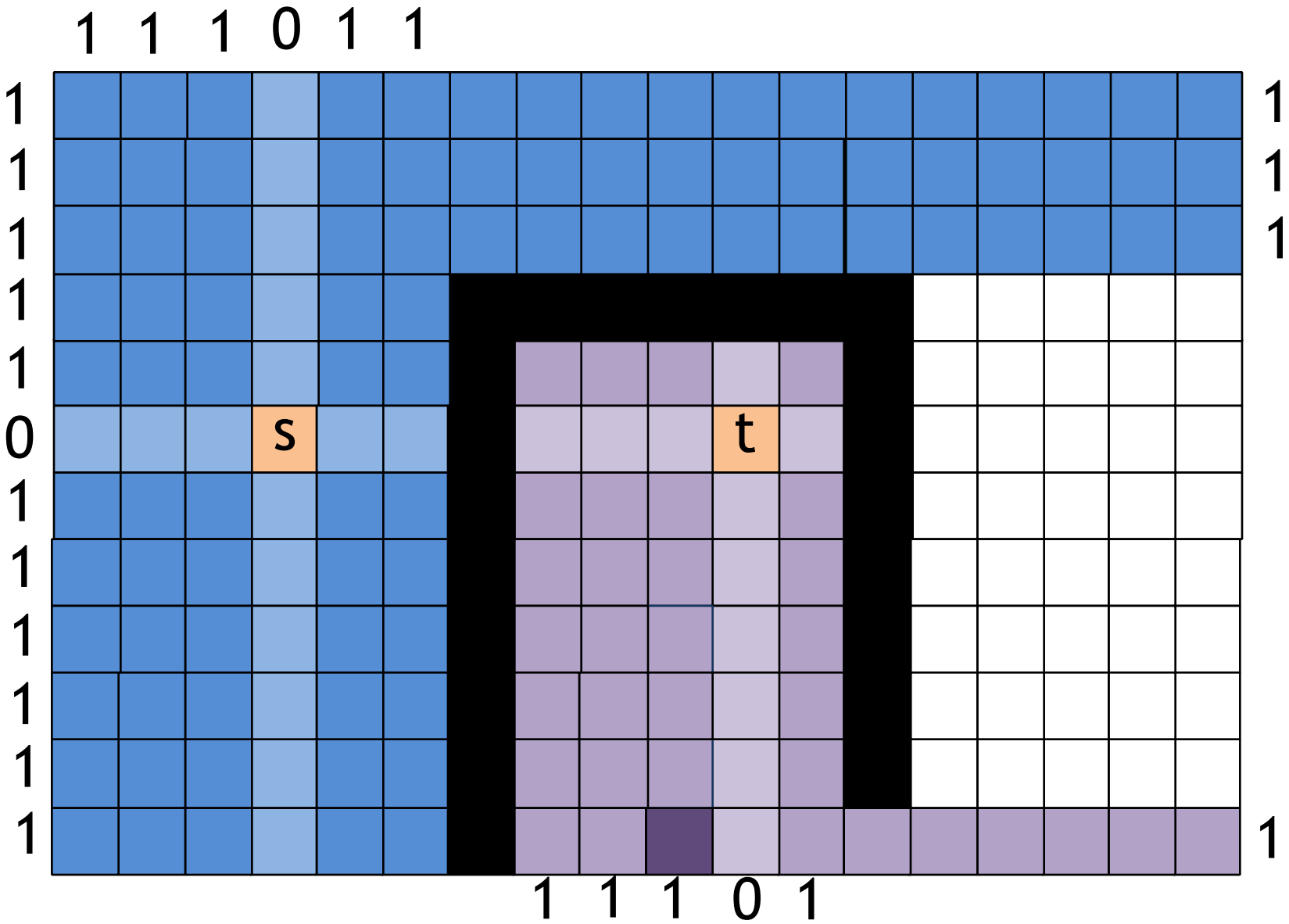
Sink Line Probe (Level 1)



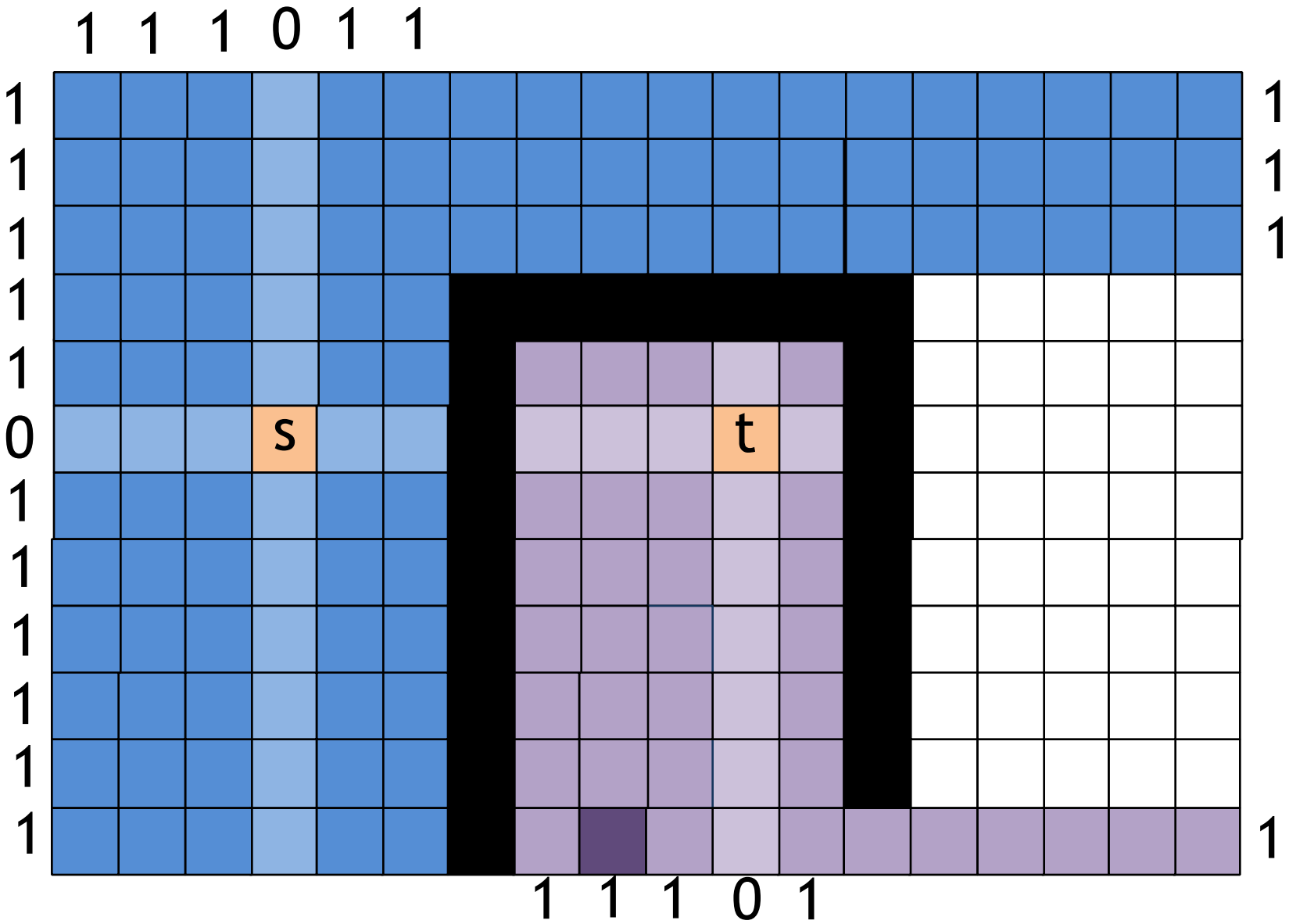
Sink Line Probe (Level 1)



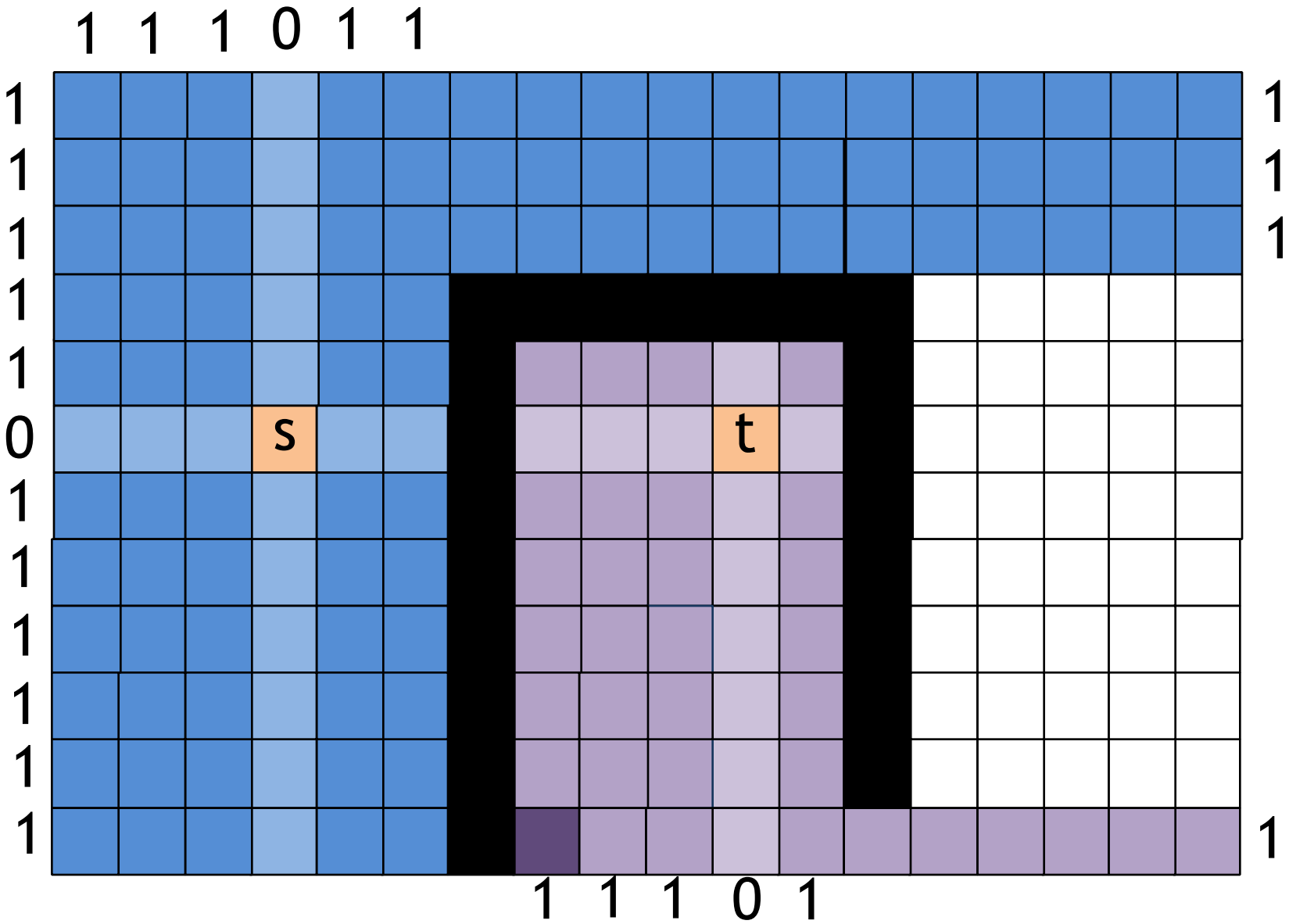
Sink Line Probe (Level 1)



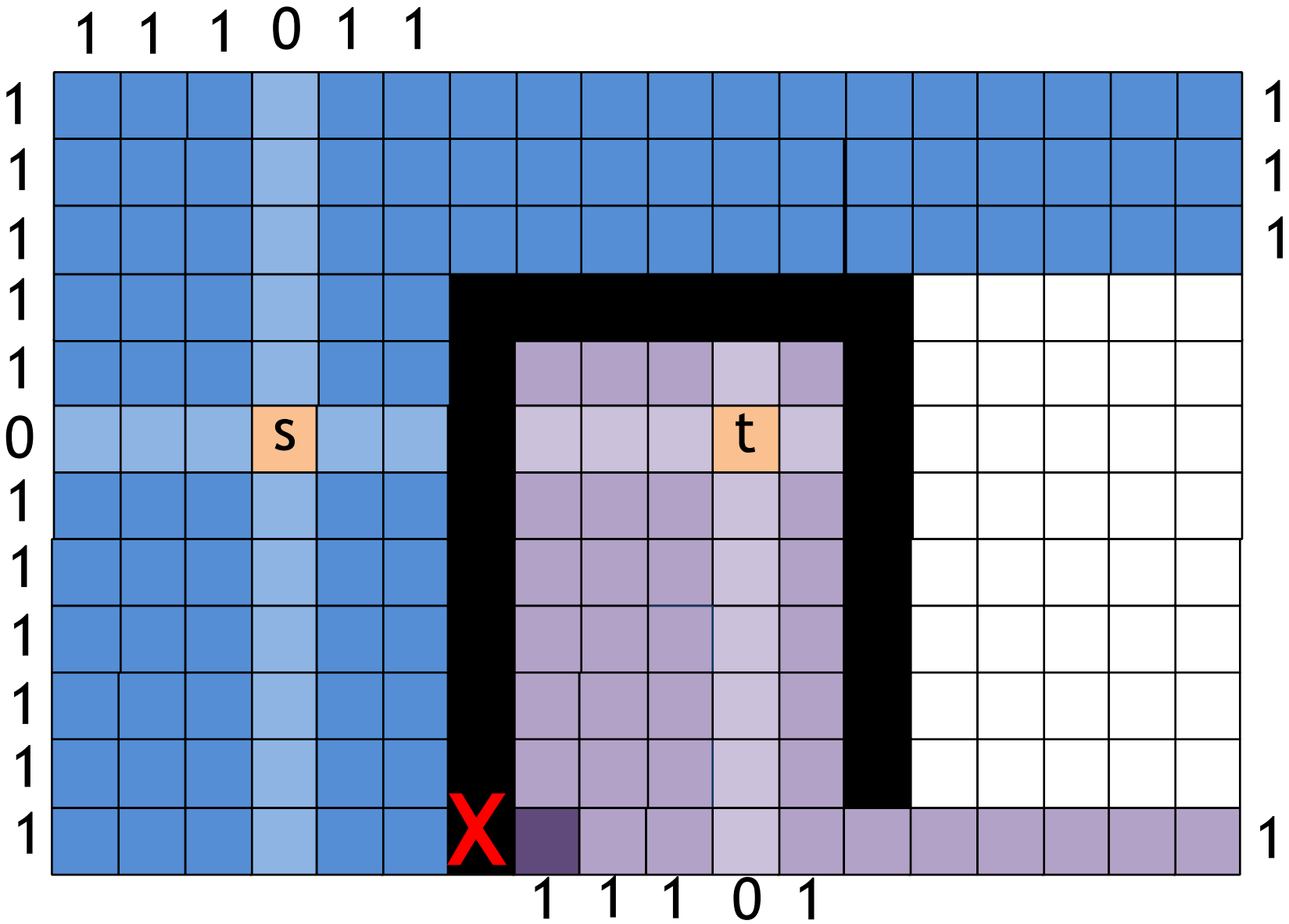
Sink Line Probe (Level 1)



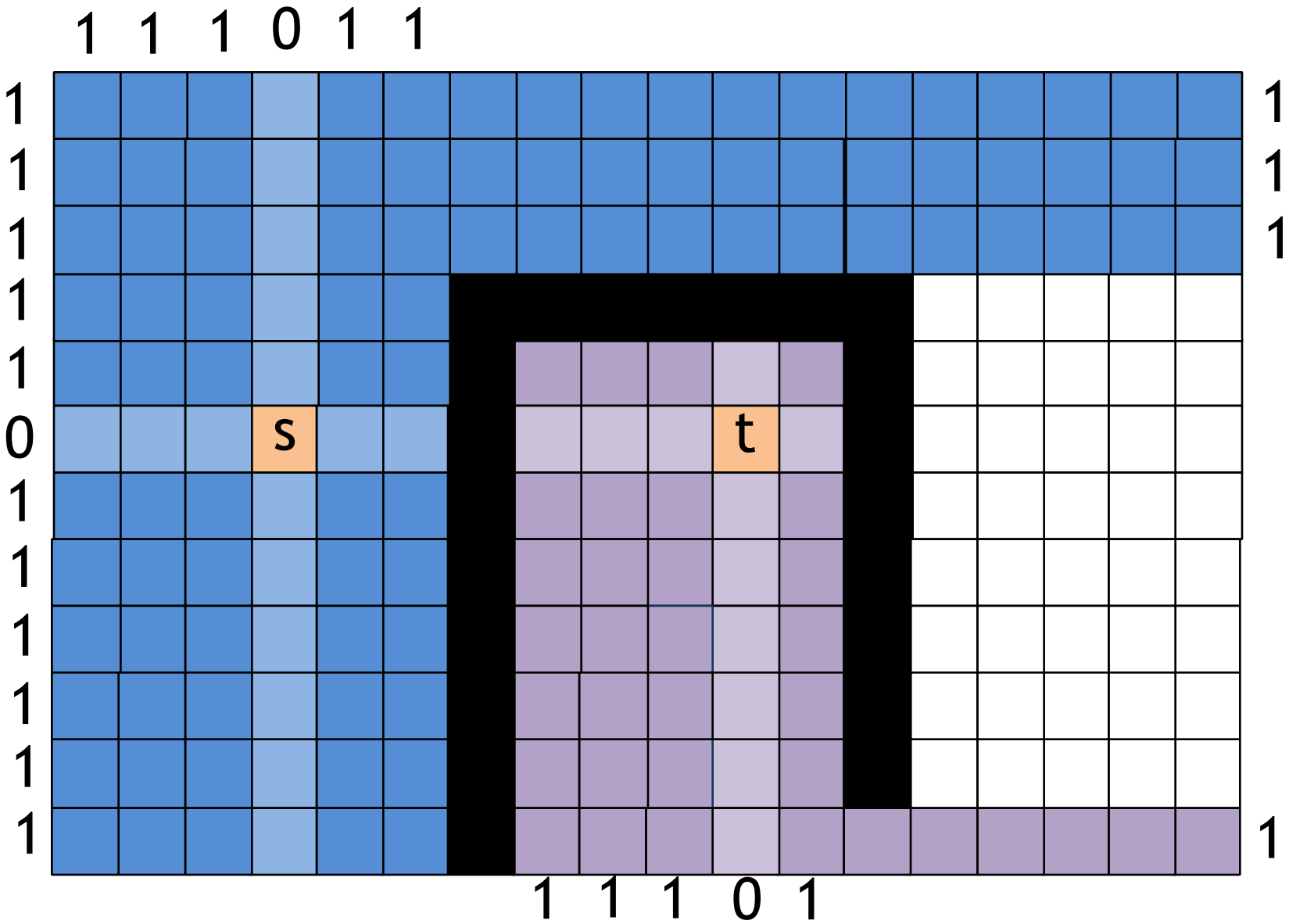
Sink Line Probe (Level 1)



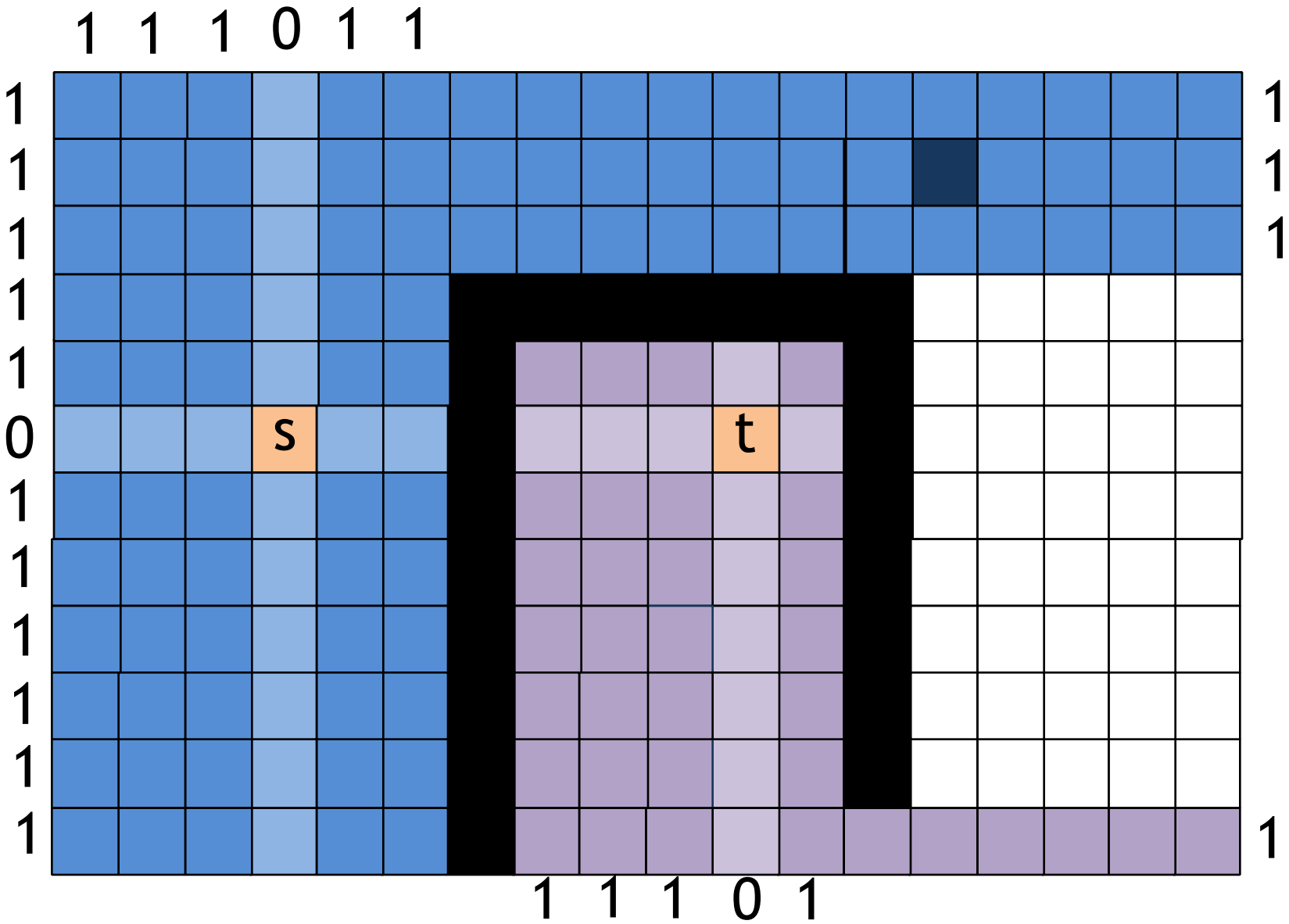
Sink Line Probe (Level 1)



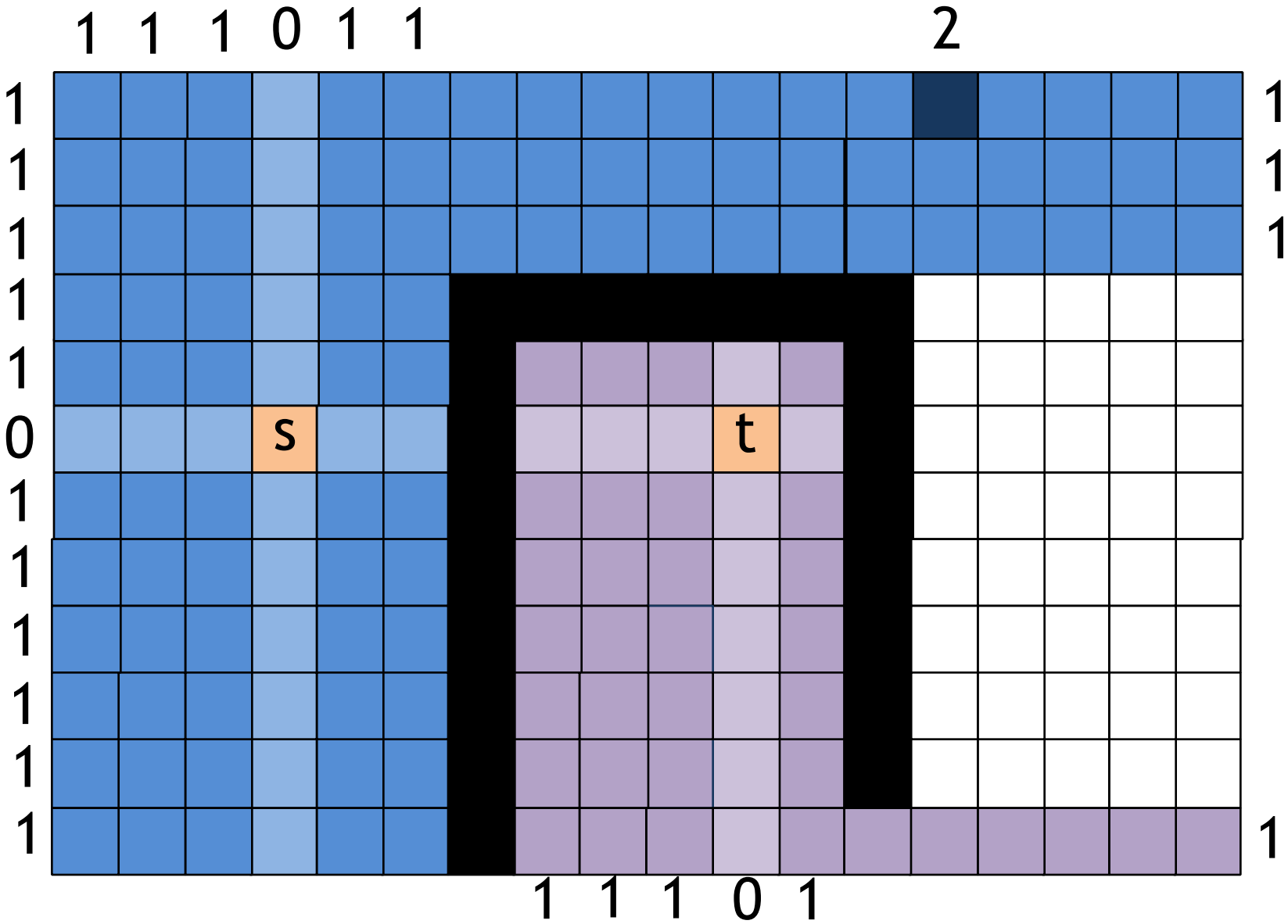
And at some point in the future…



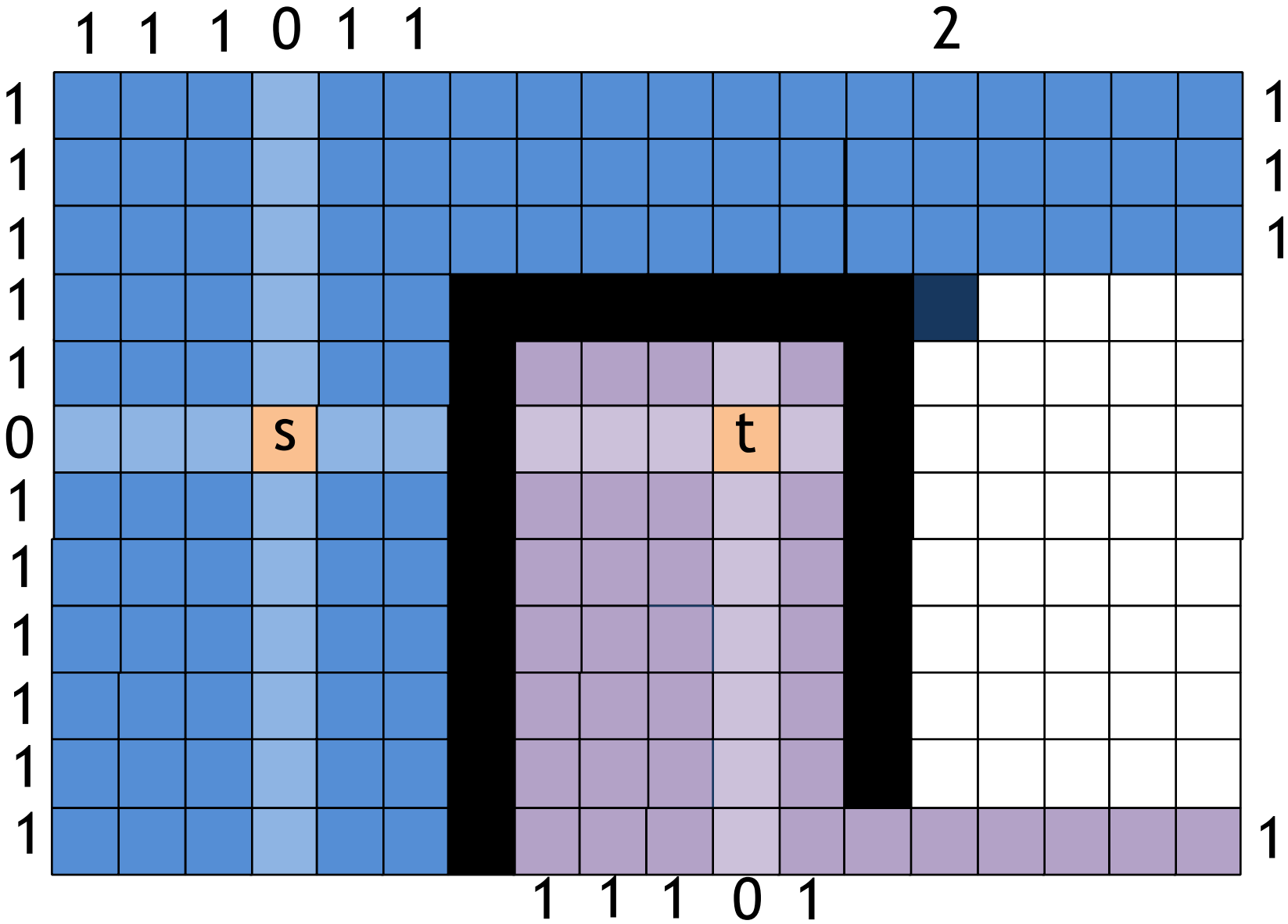
Source Line Probe (Level 2)



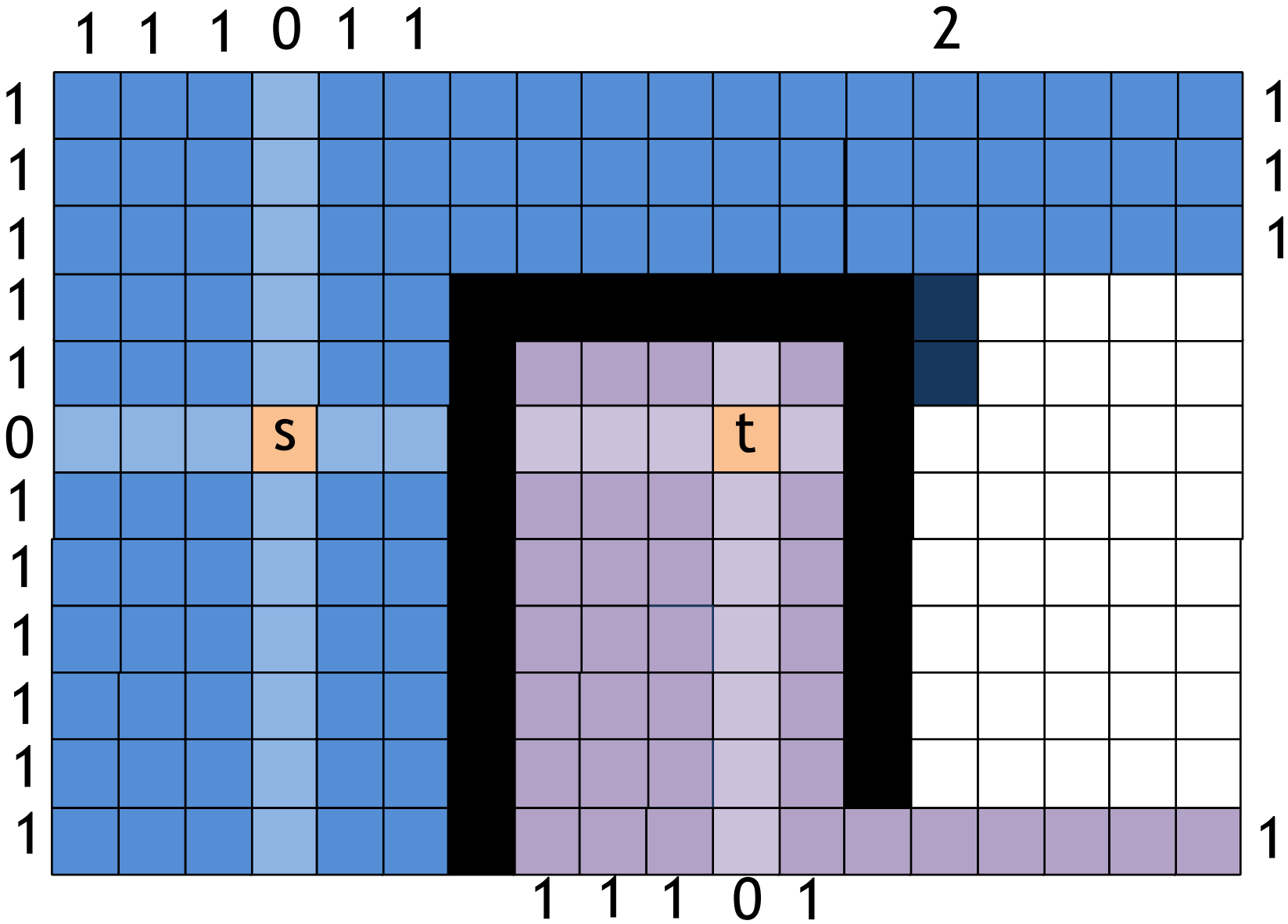
Source Line Probe (Level 2)



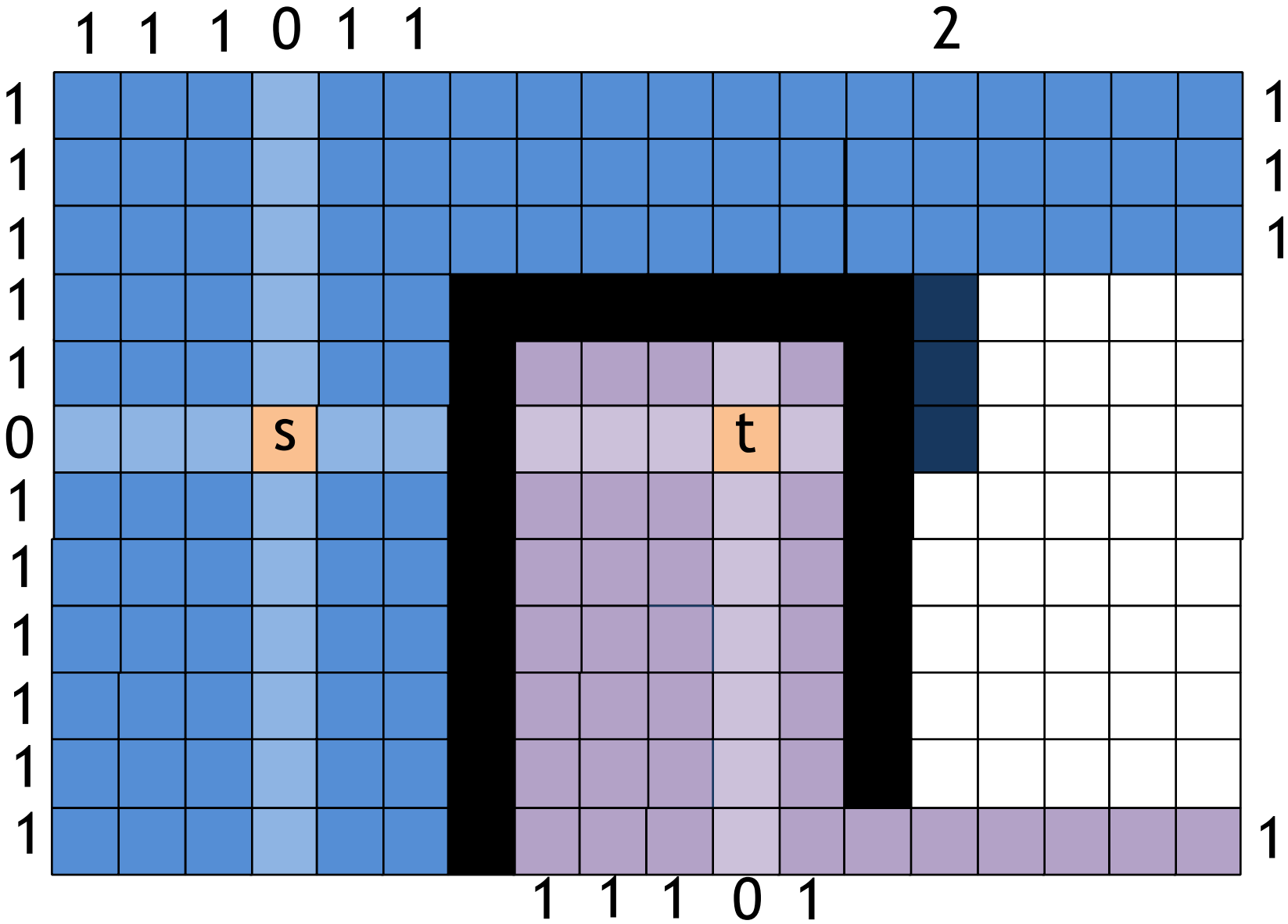
Source Line Probe (Level 2)



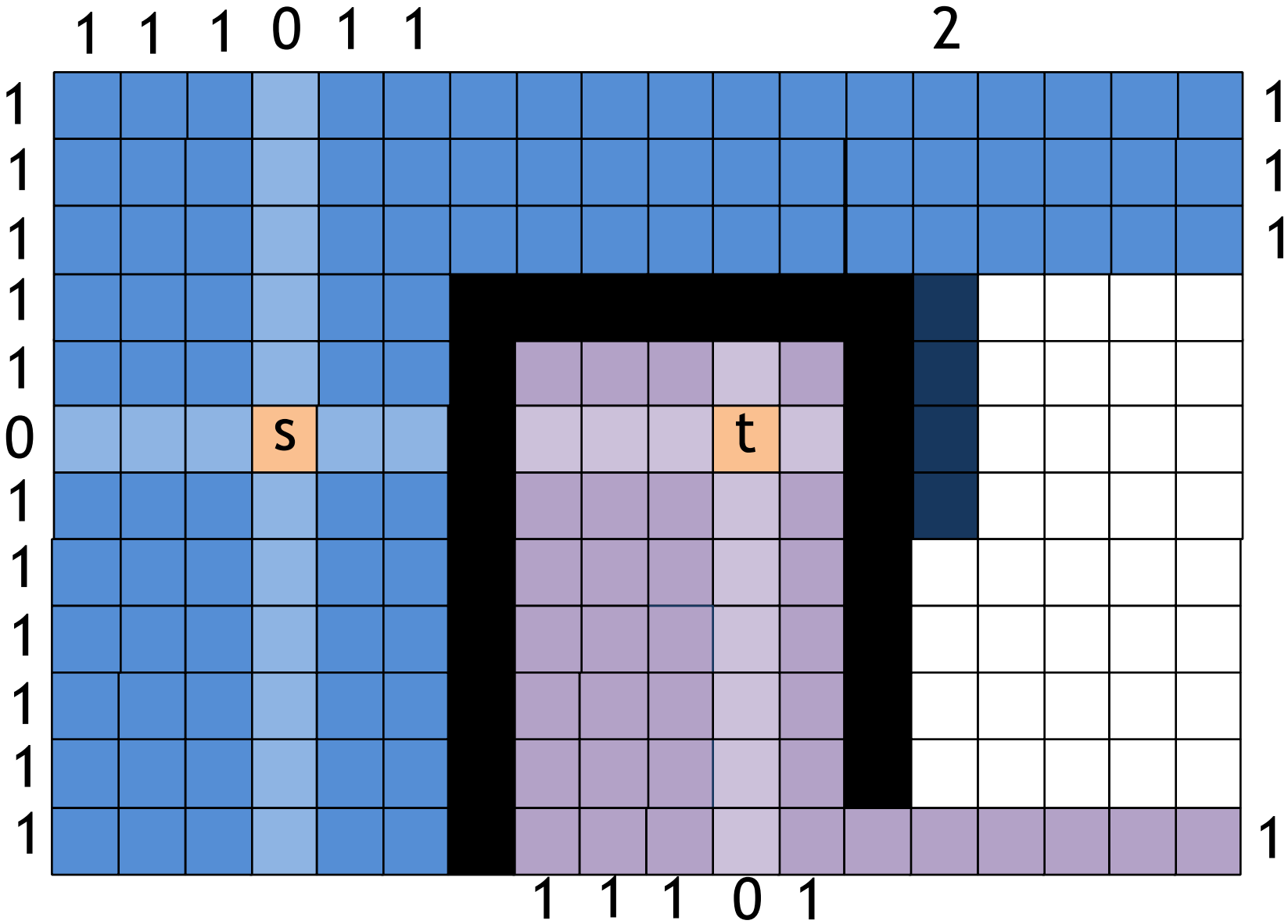
Source Line Probe (Level 2)



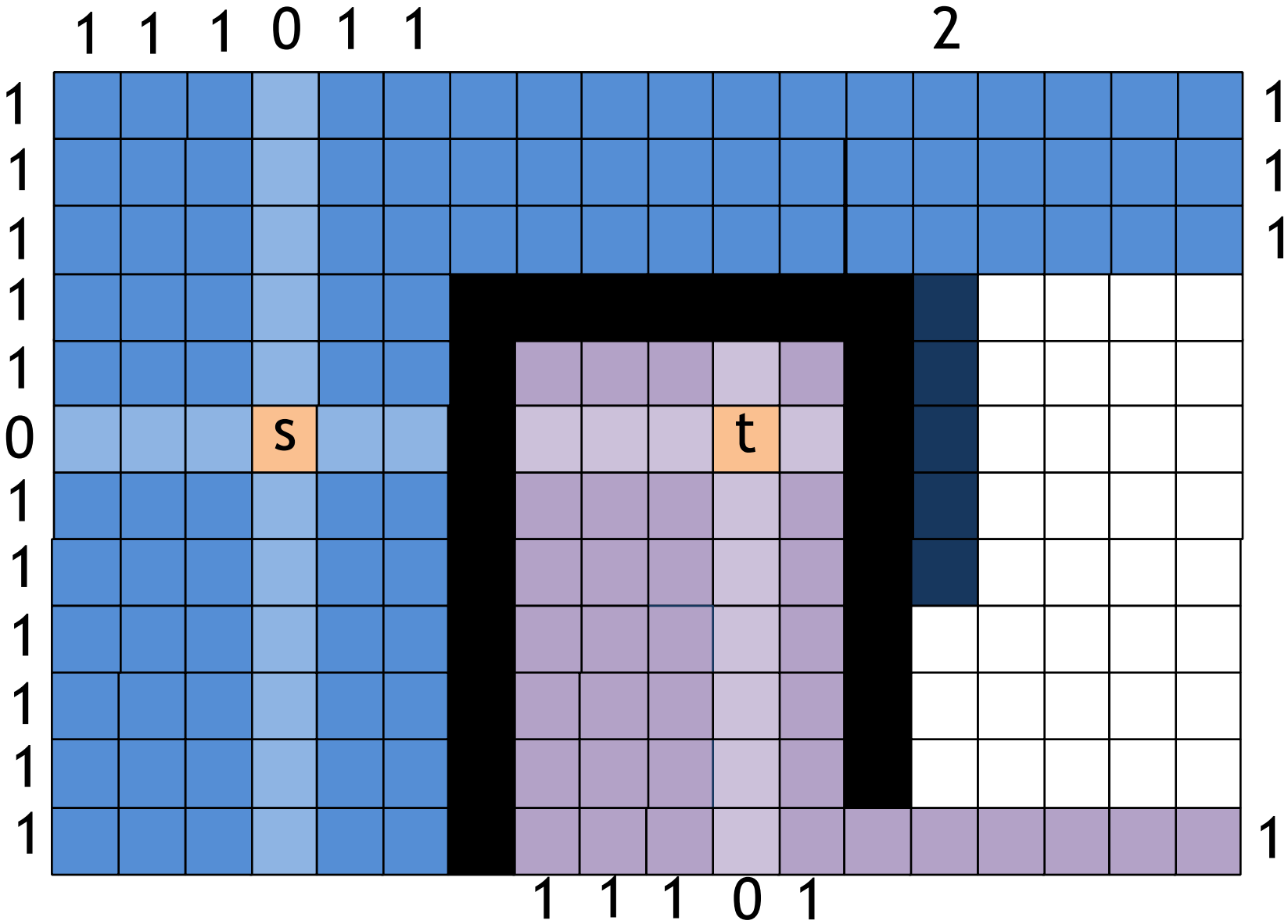
Source Line Probe (Level 2)



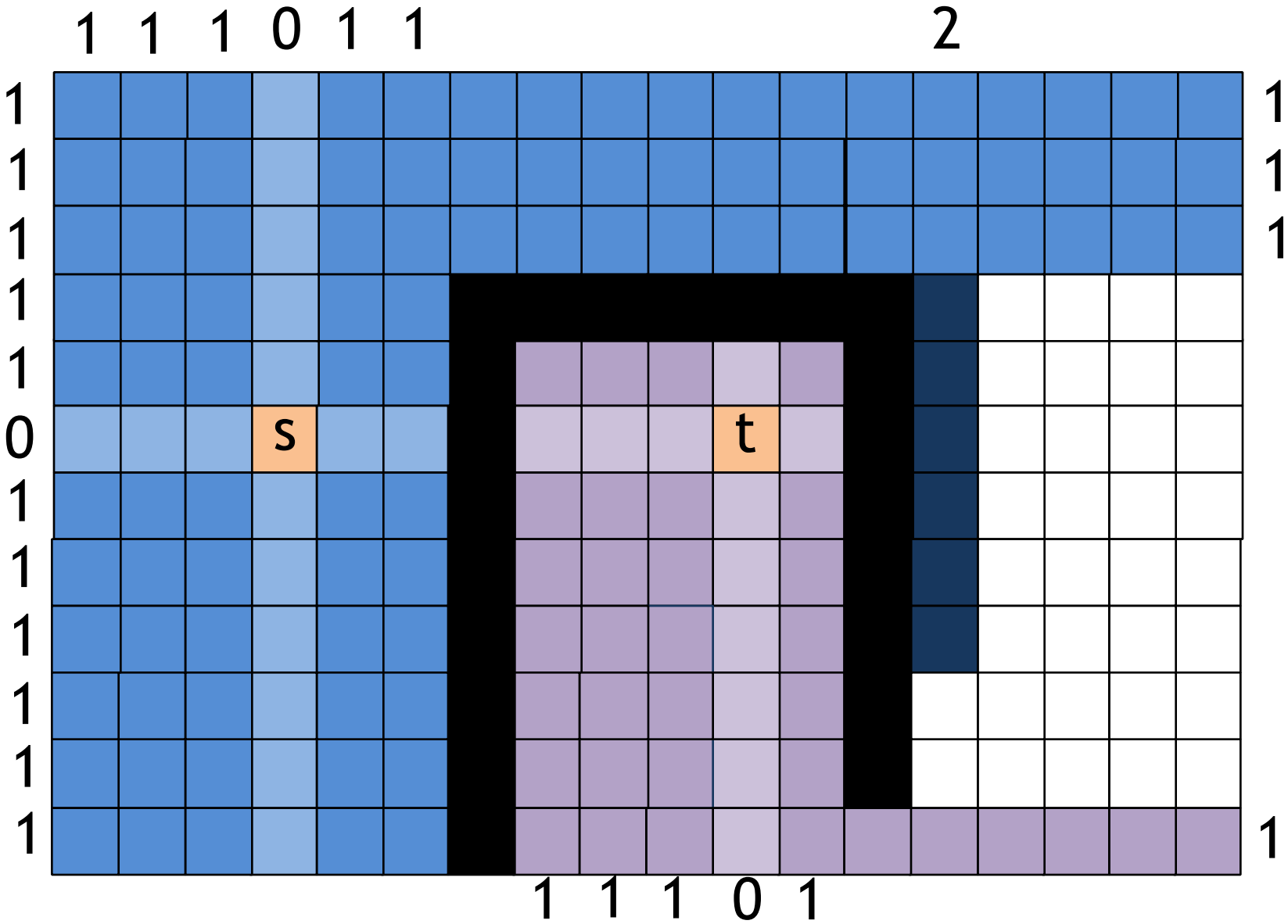
Source Line Probe (Level 2)



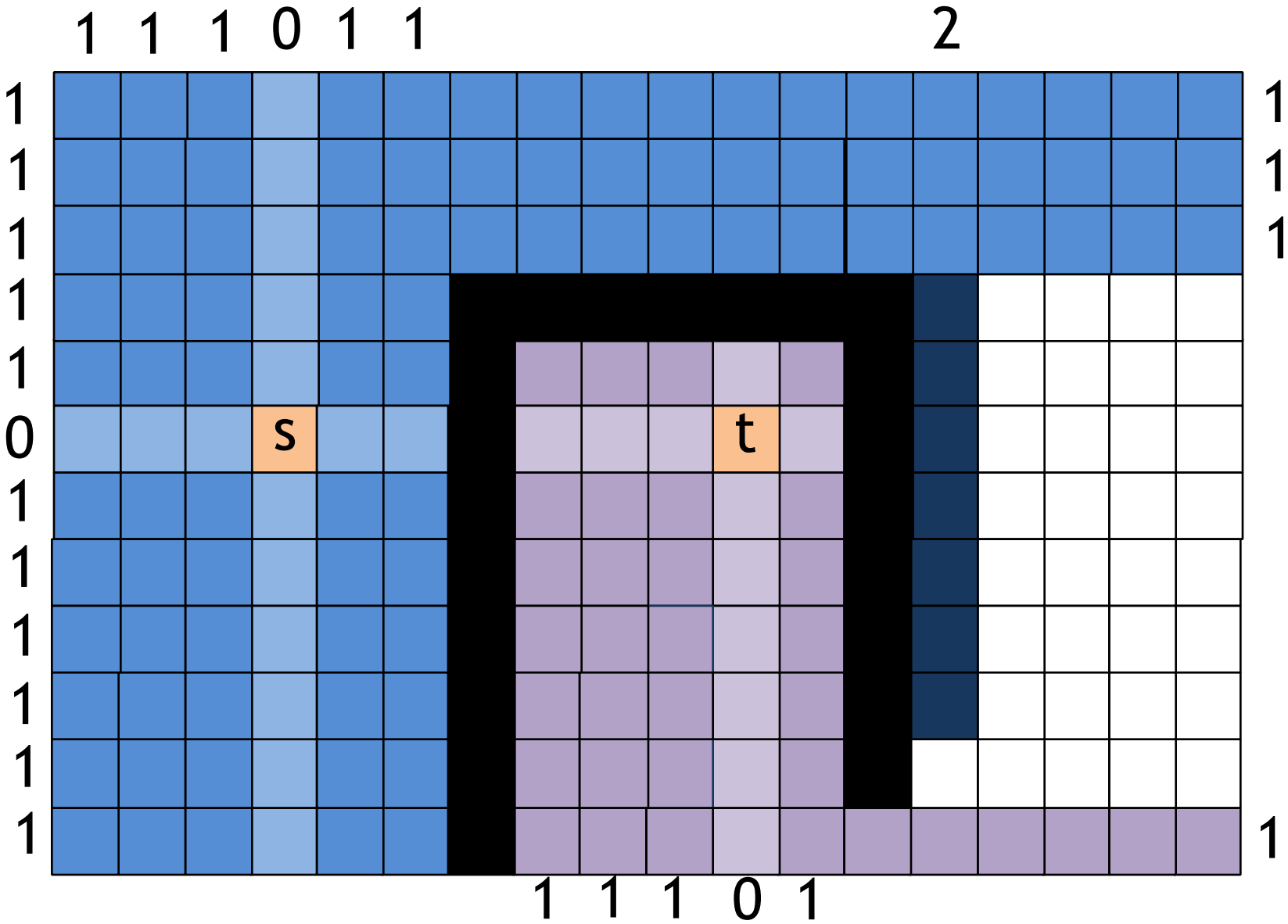
Source Line Probe (Level 2)



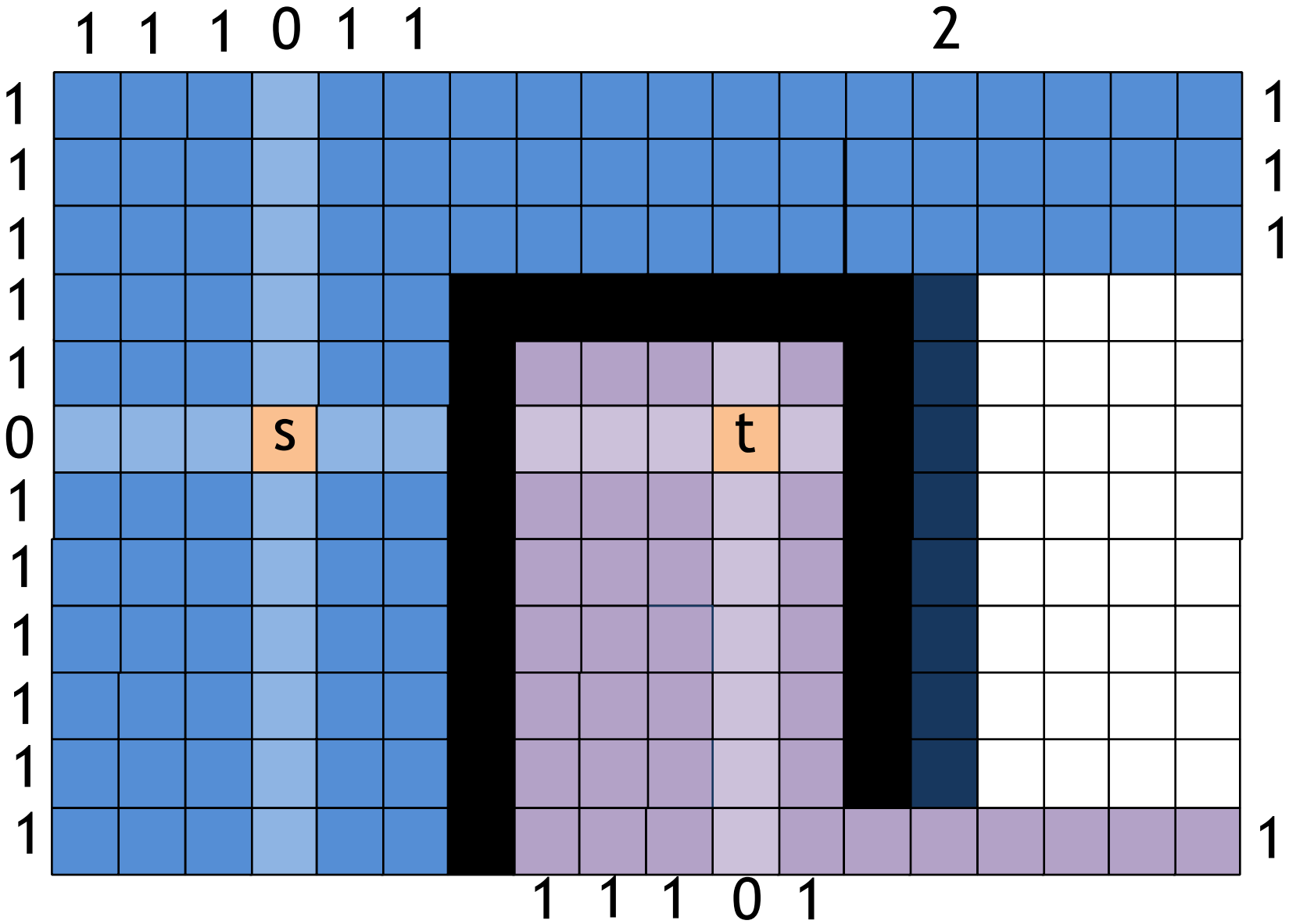
Source Line Probe (Level 2)



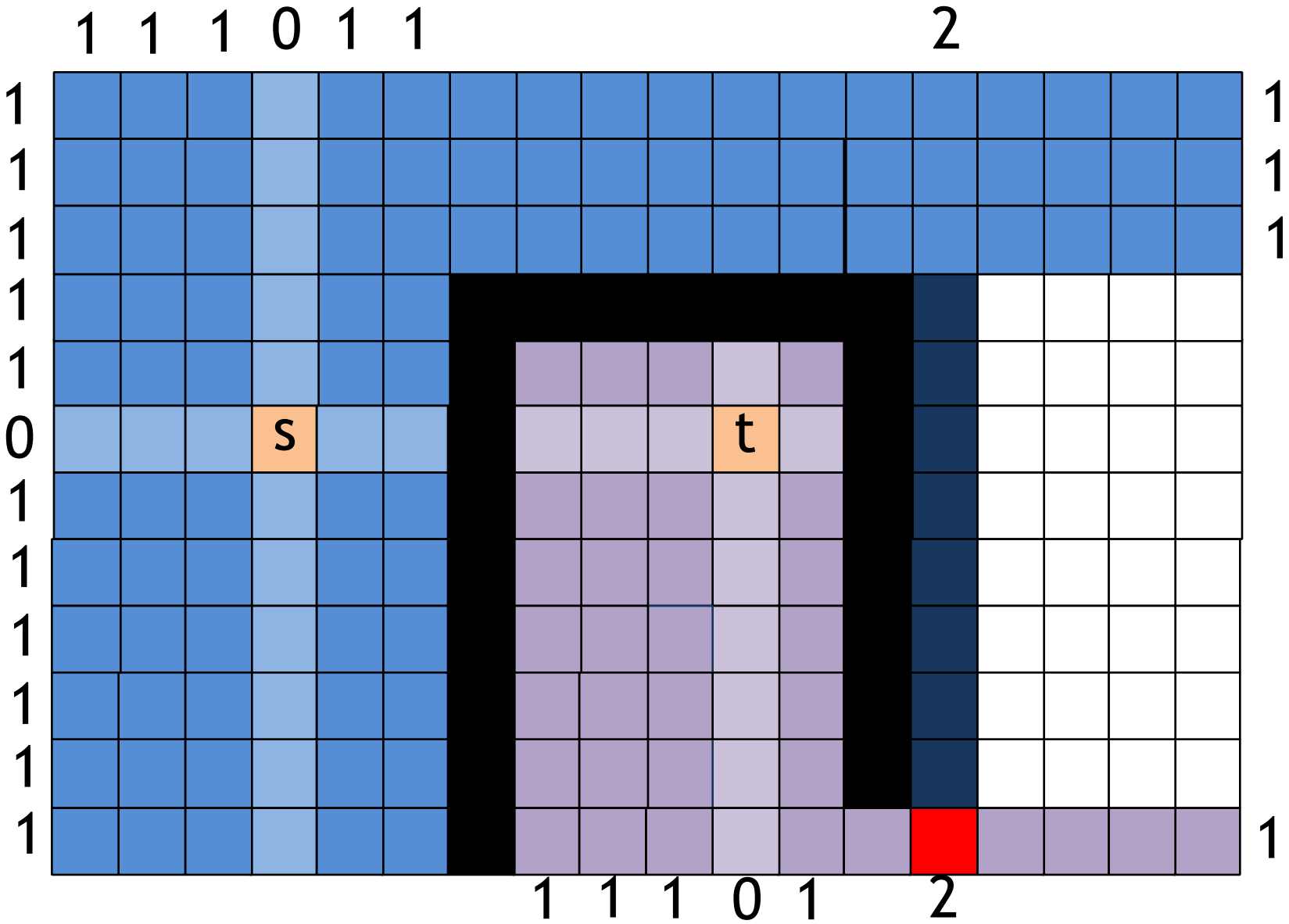
Source Line Probe (Level 2)



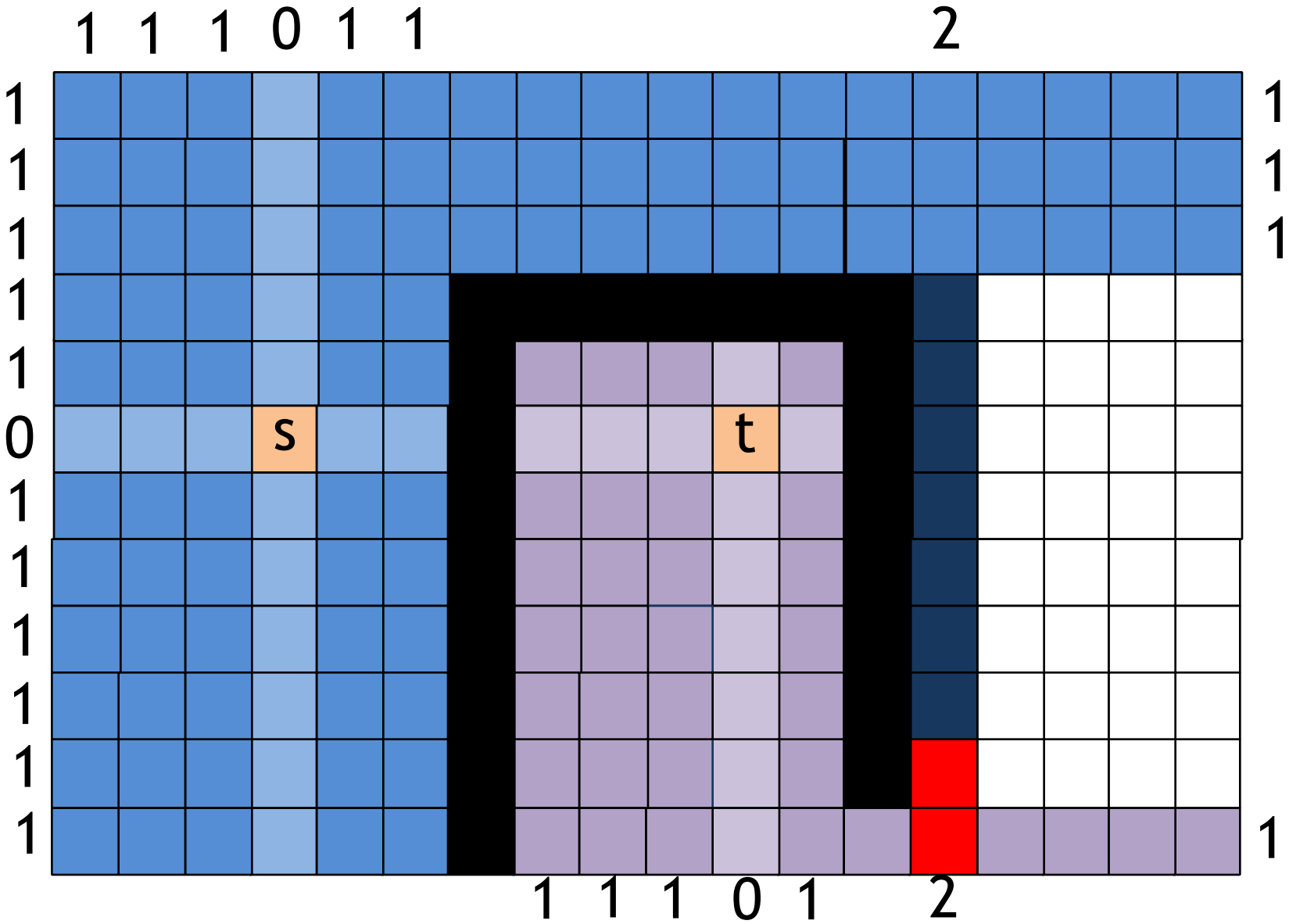
Source Line Probe (Level 2)



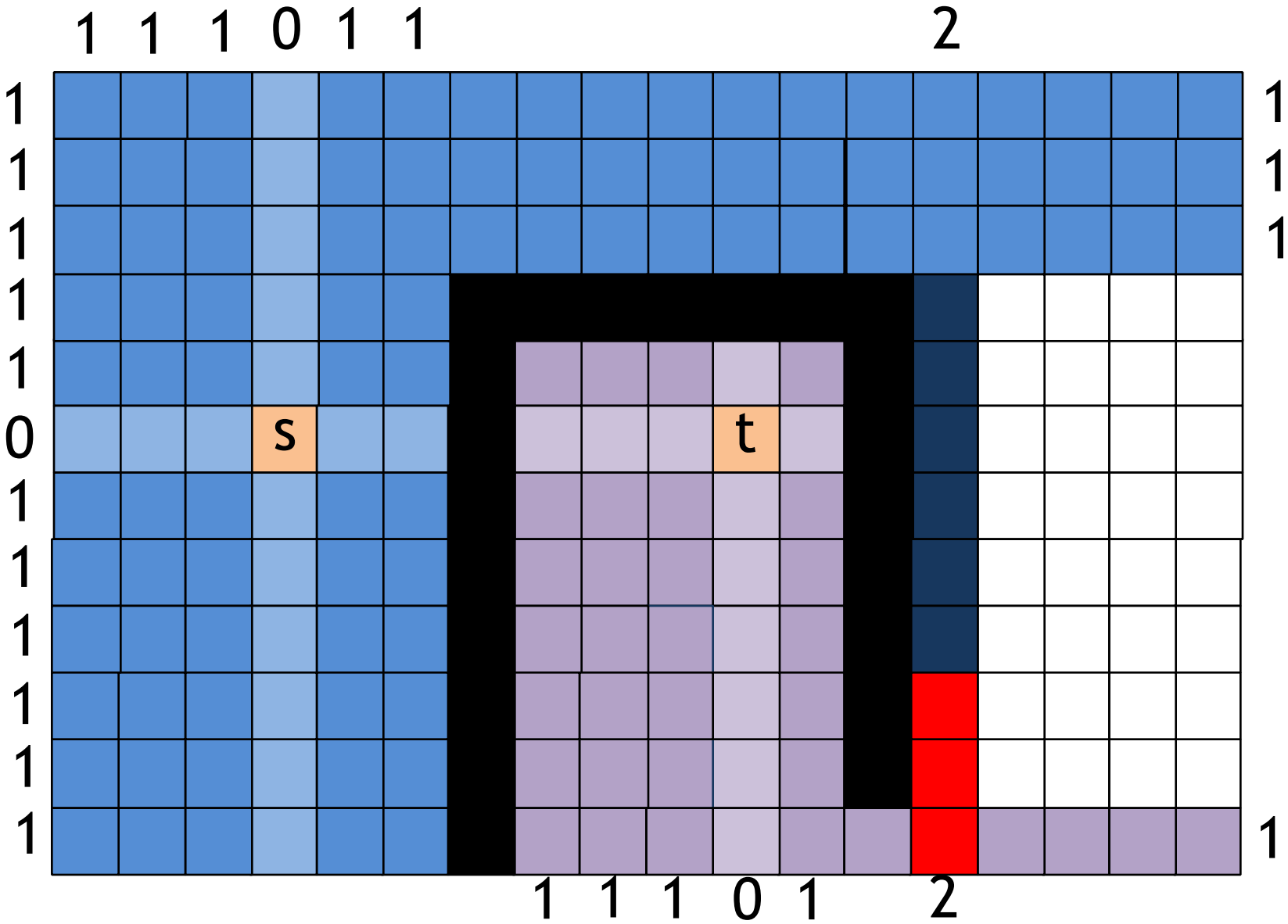
Source Line Probe (Level 2)



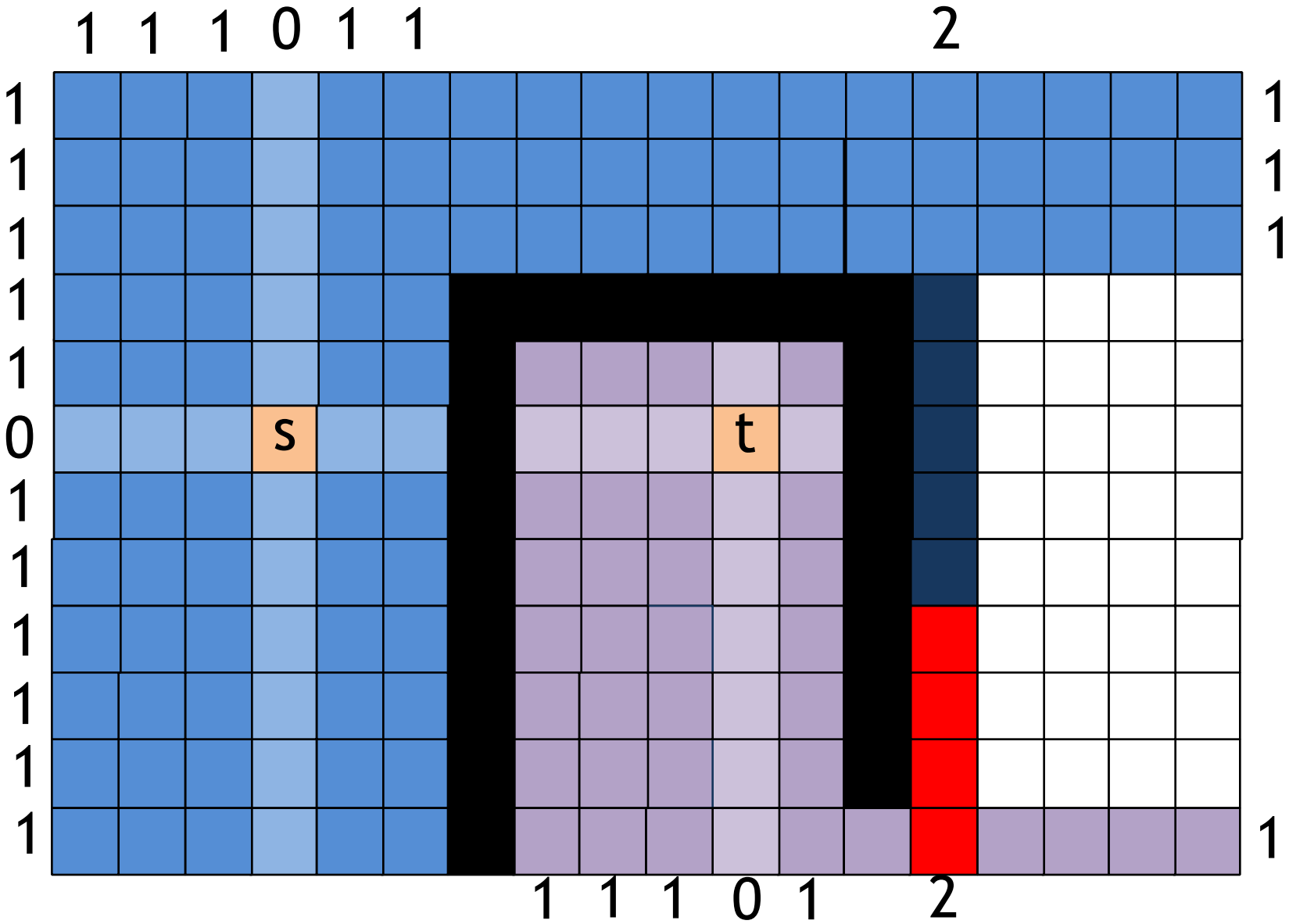
Backtrace Toward the Source



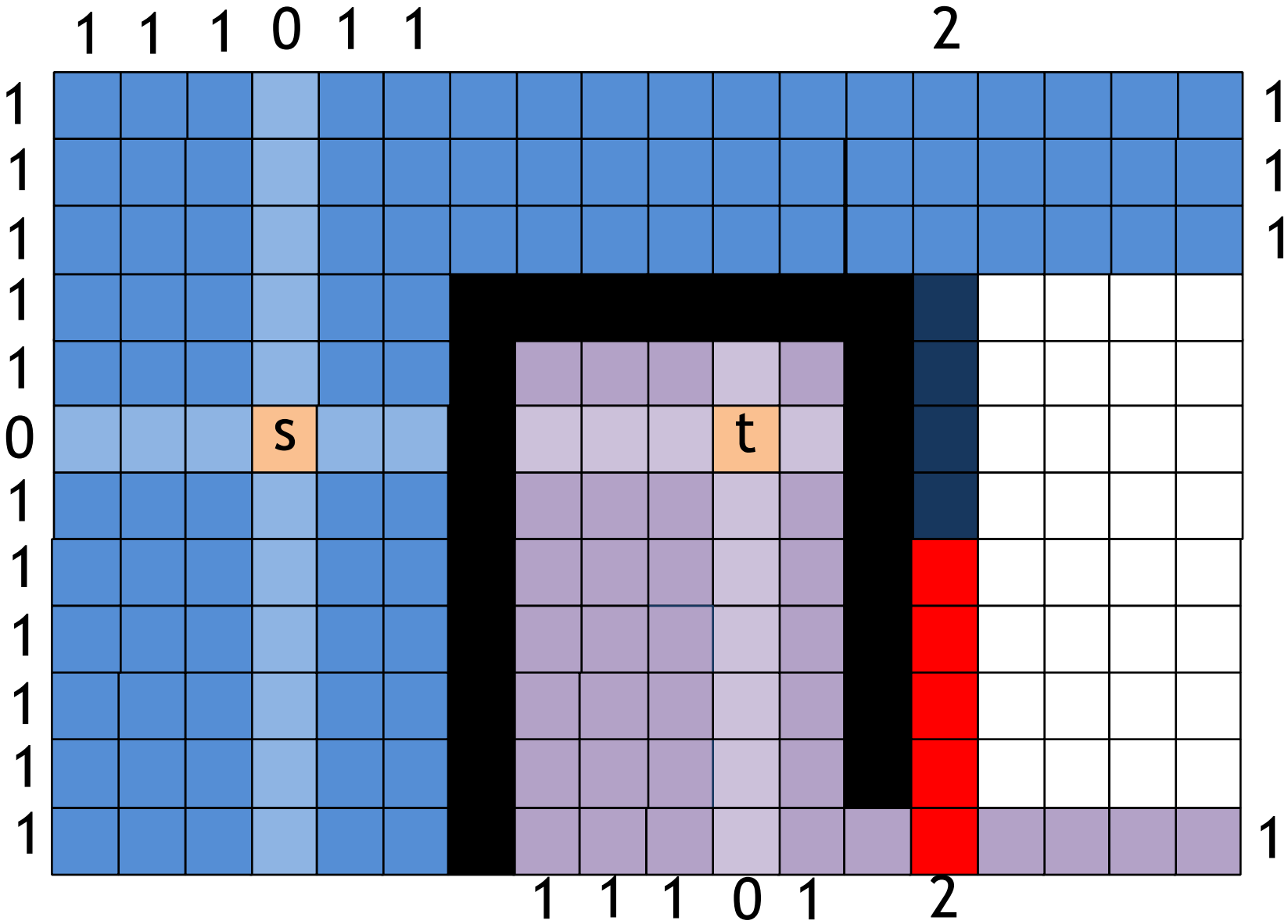
Backtrace Toward the Source



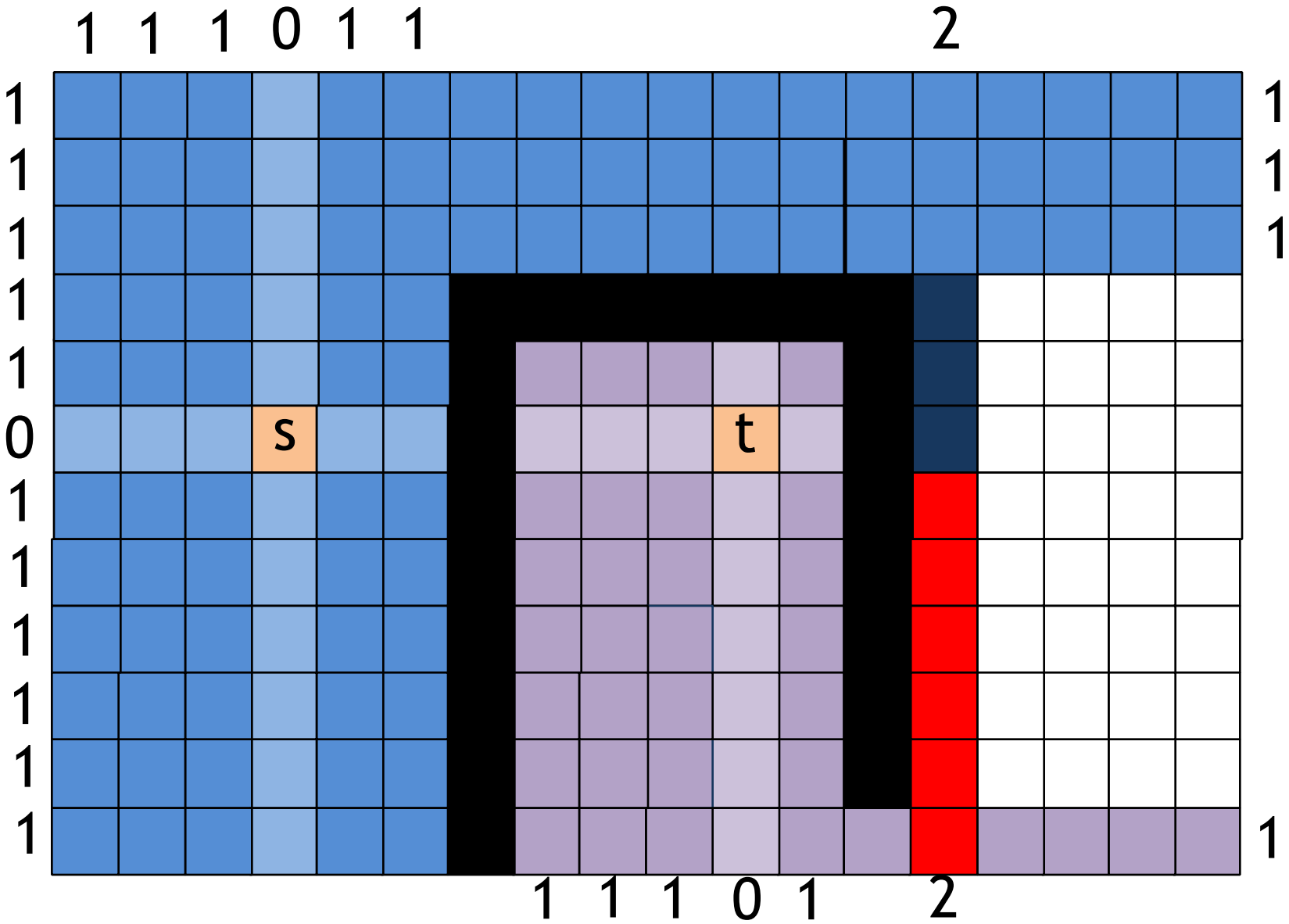
Backtrace Toward the Source



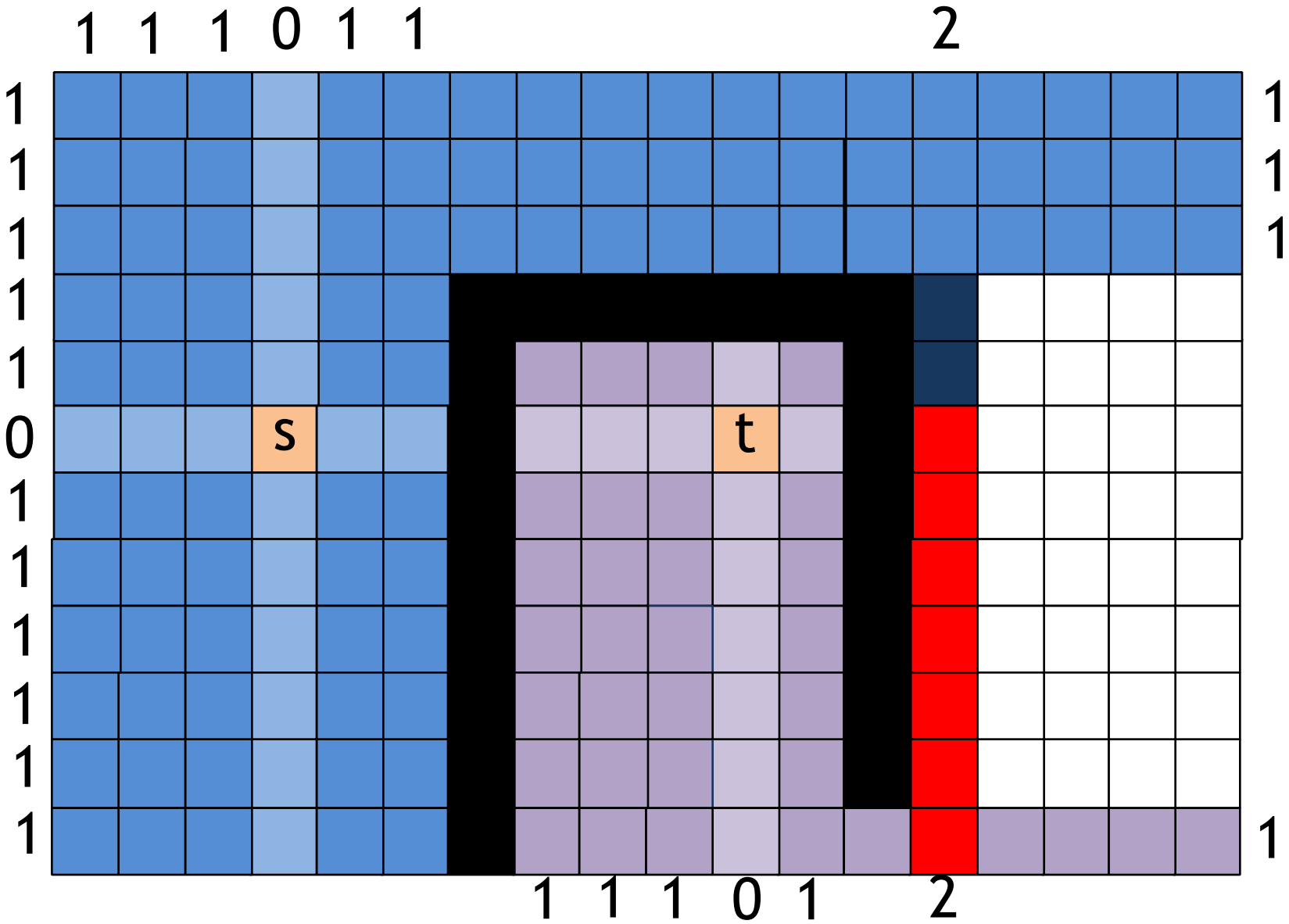
Backtrace Toward the Source



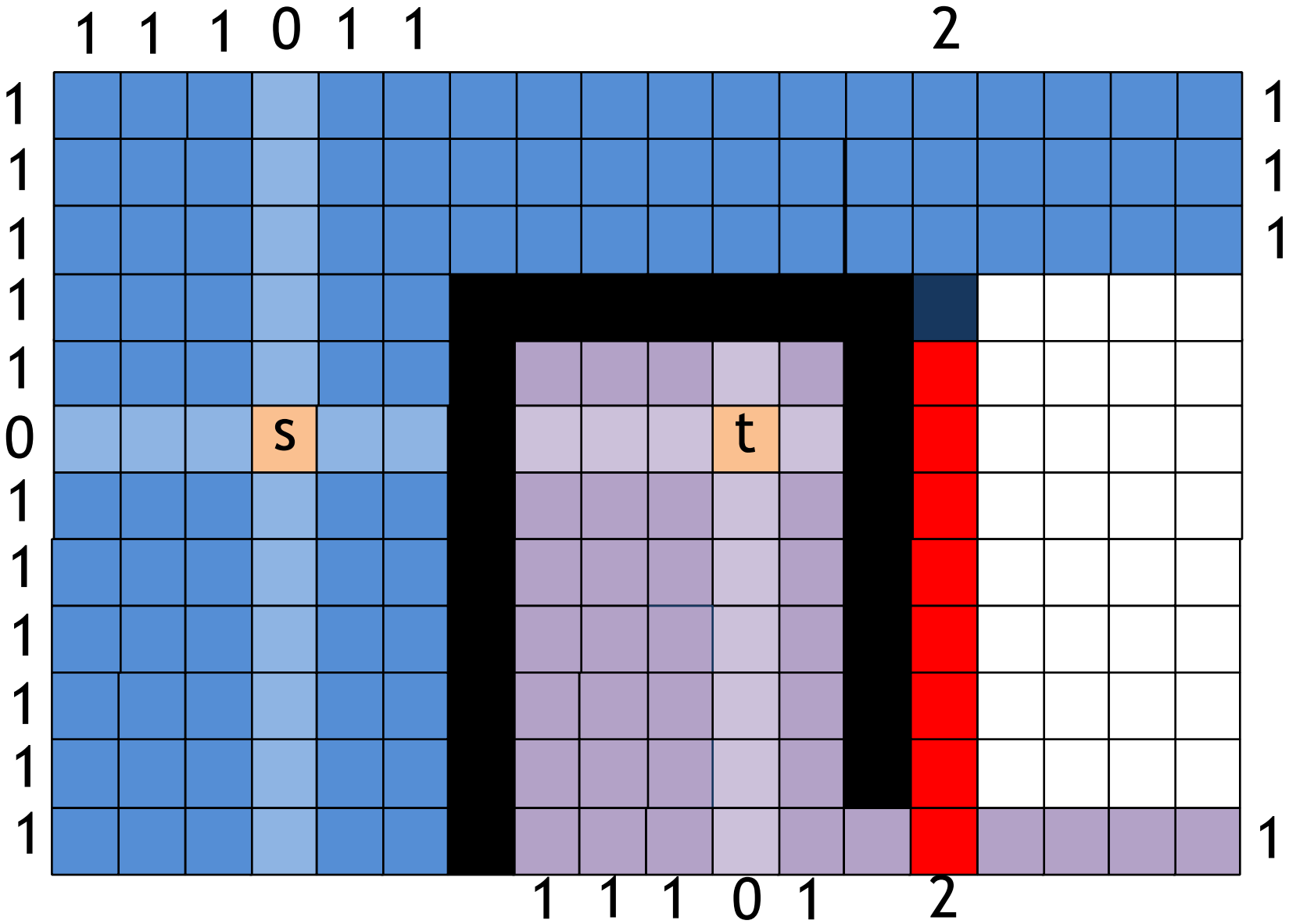
Backtrace Toward the Source



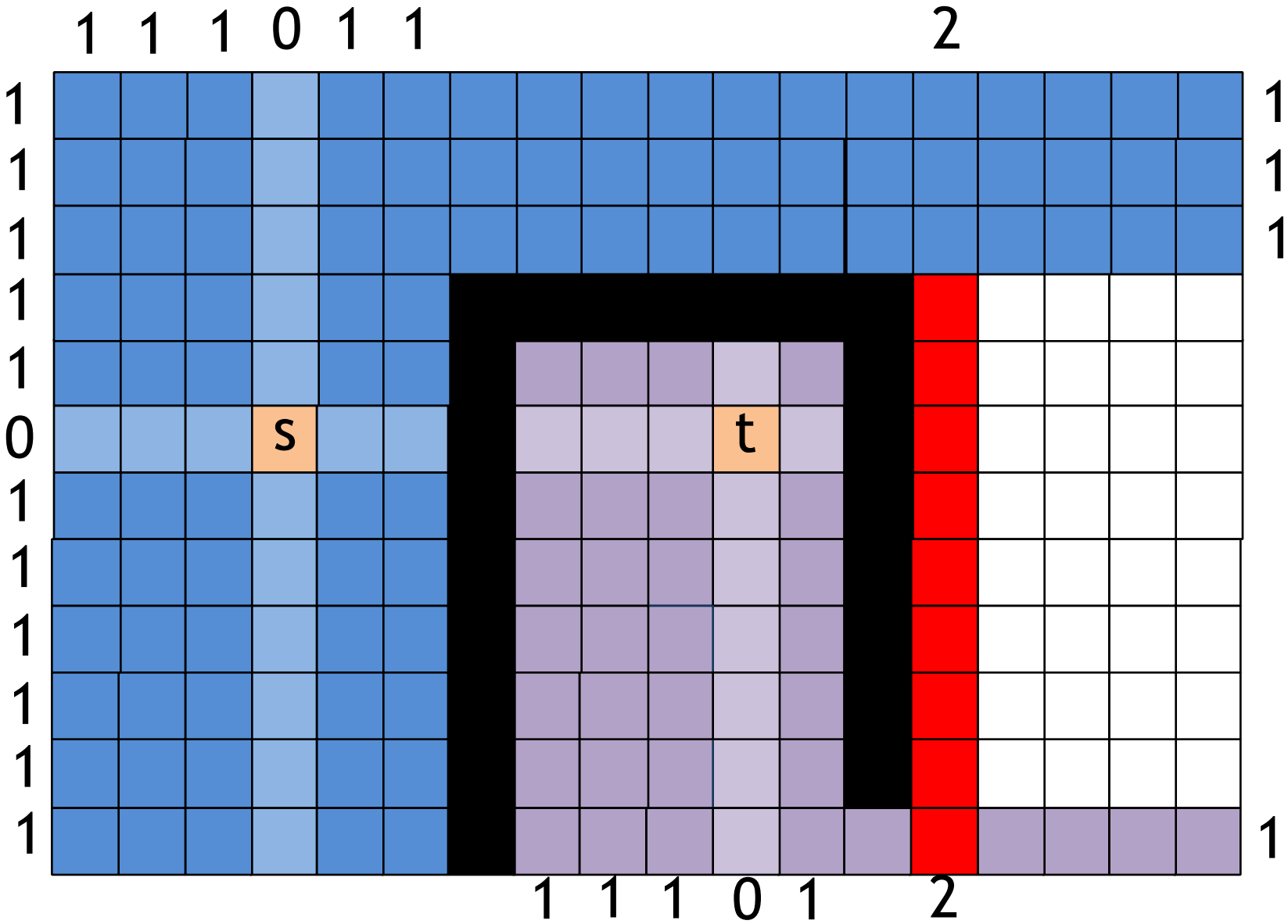
Backtrace Toward the Source



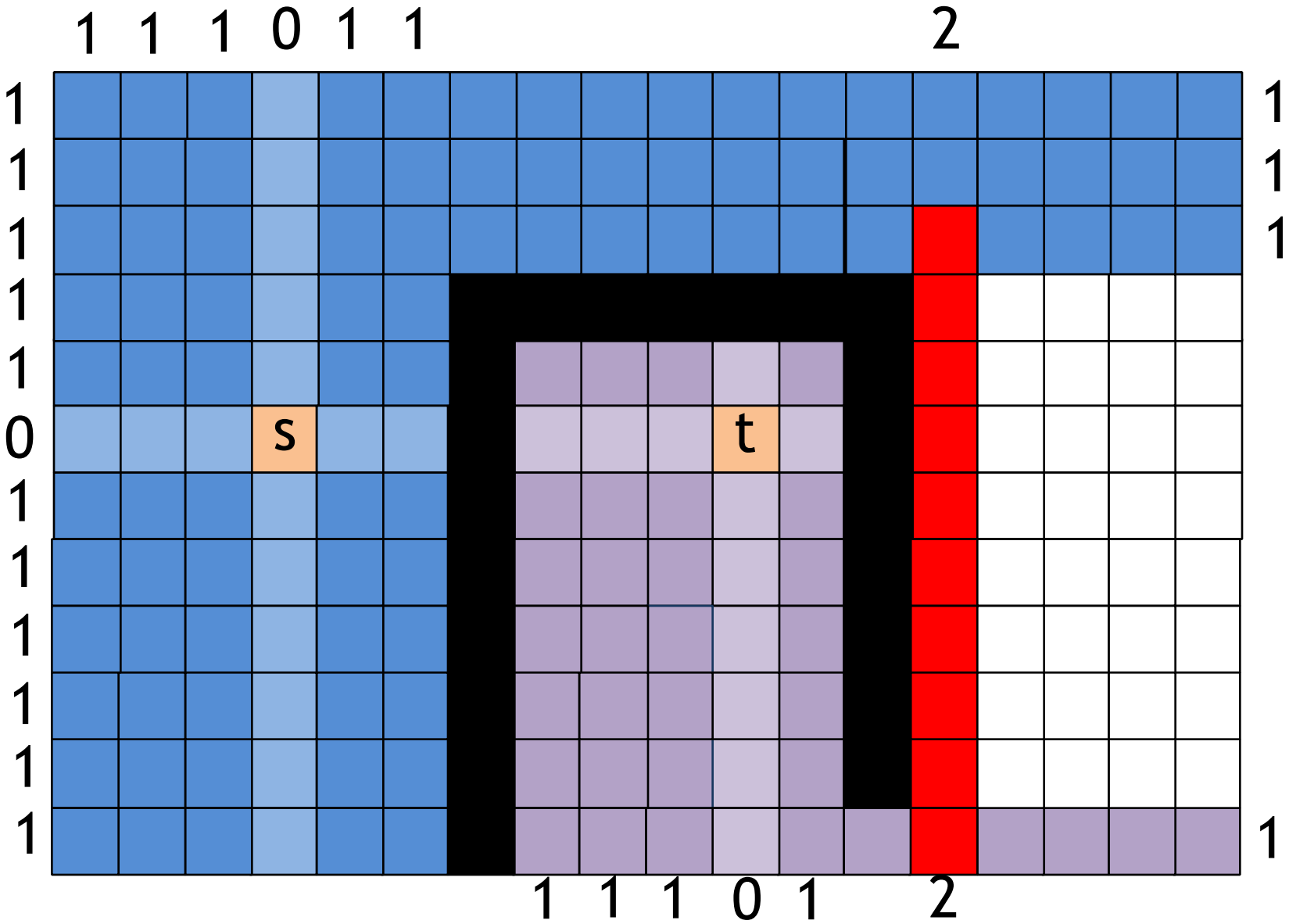
Backtrace Toward the Source



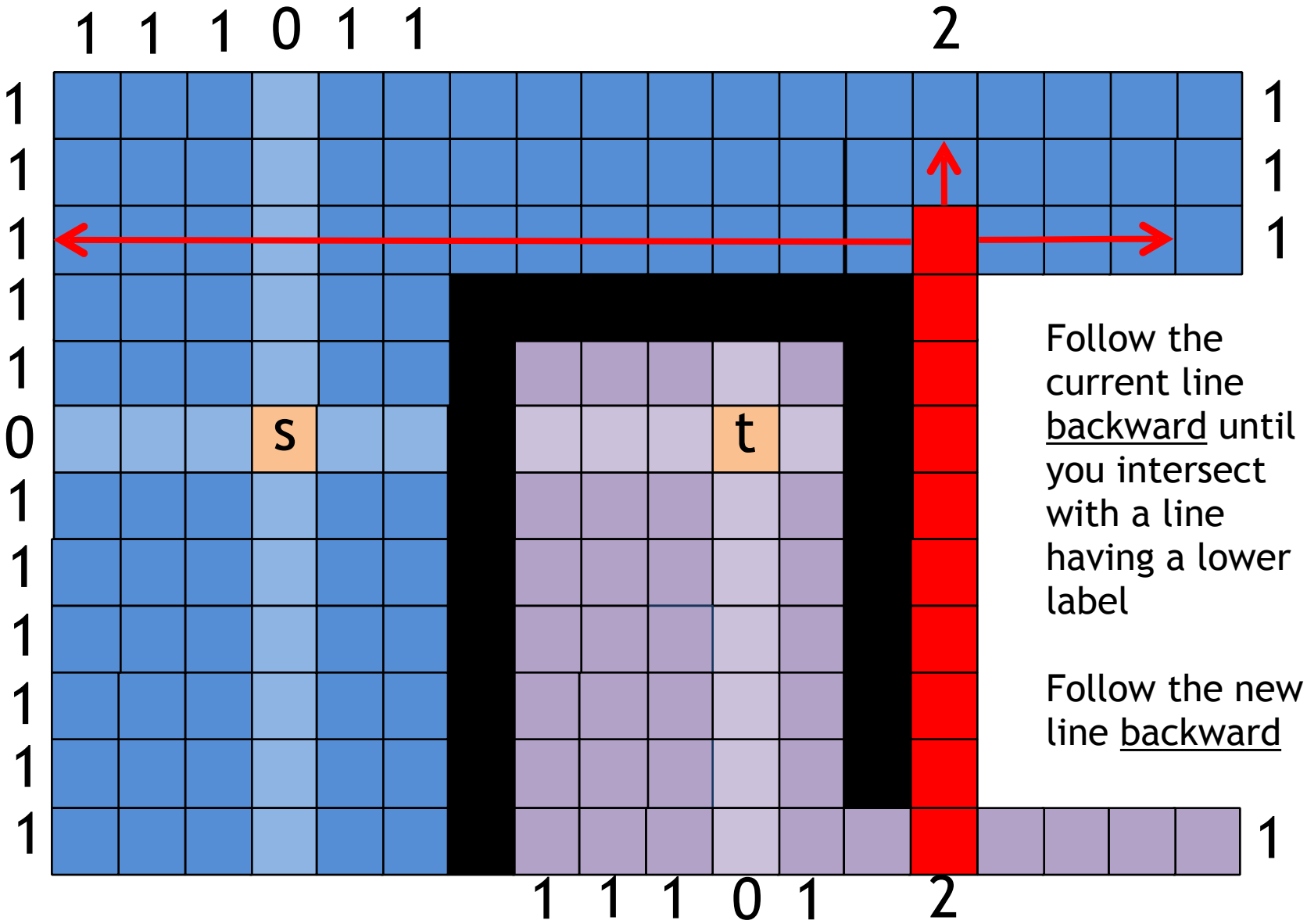
Backtrace Toward the Source



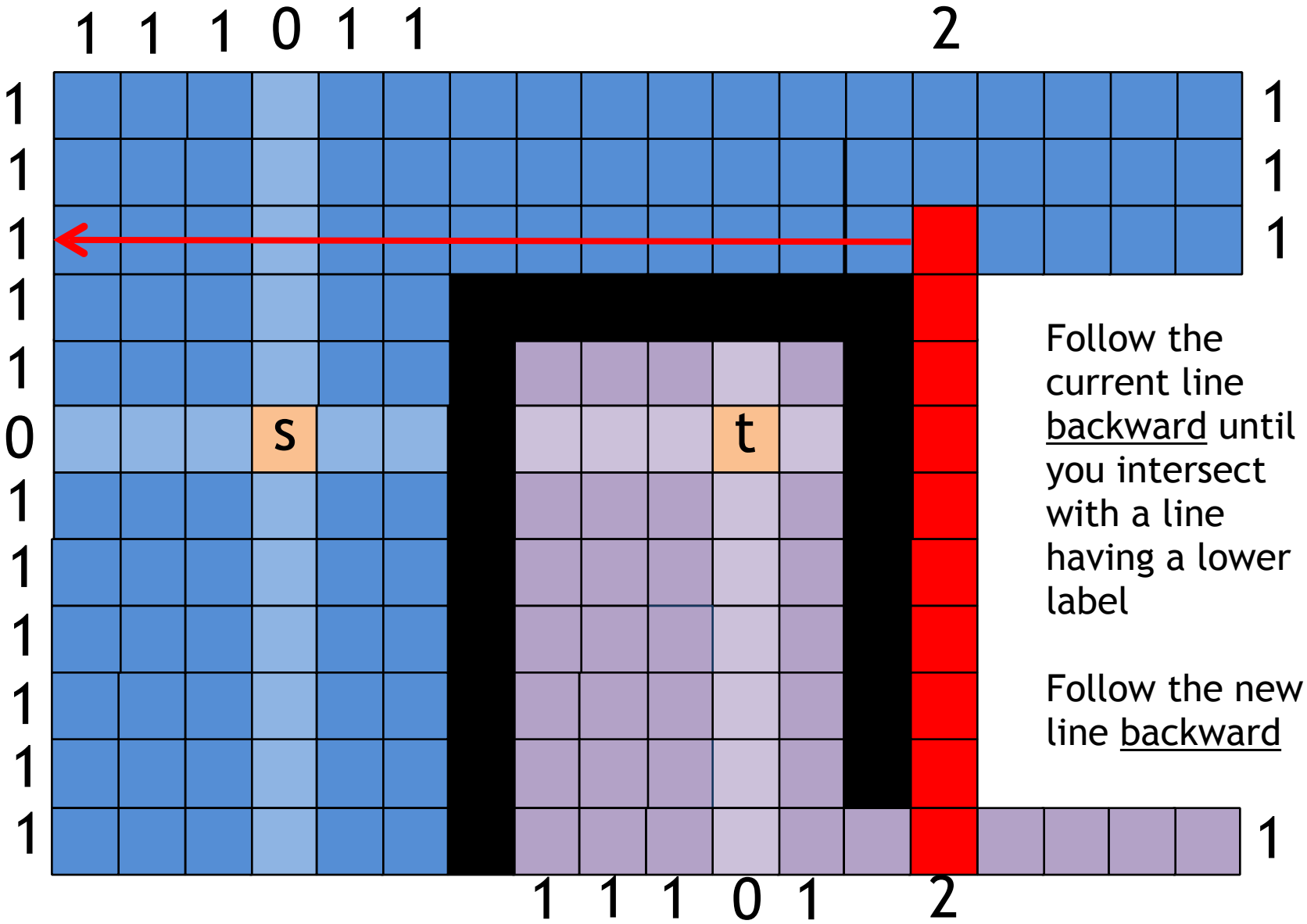
Backtrace Toward the Source



Backtrace Toward the Source



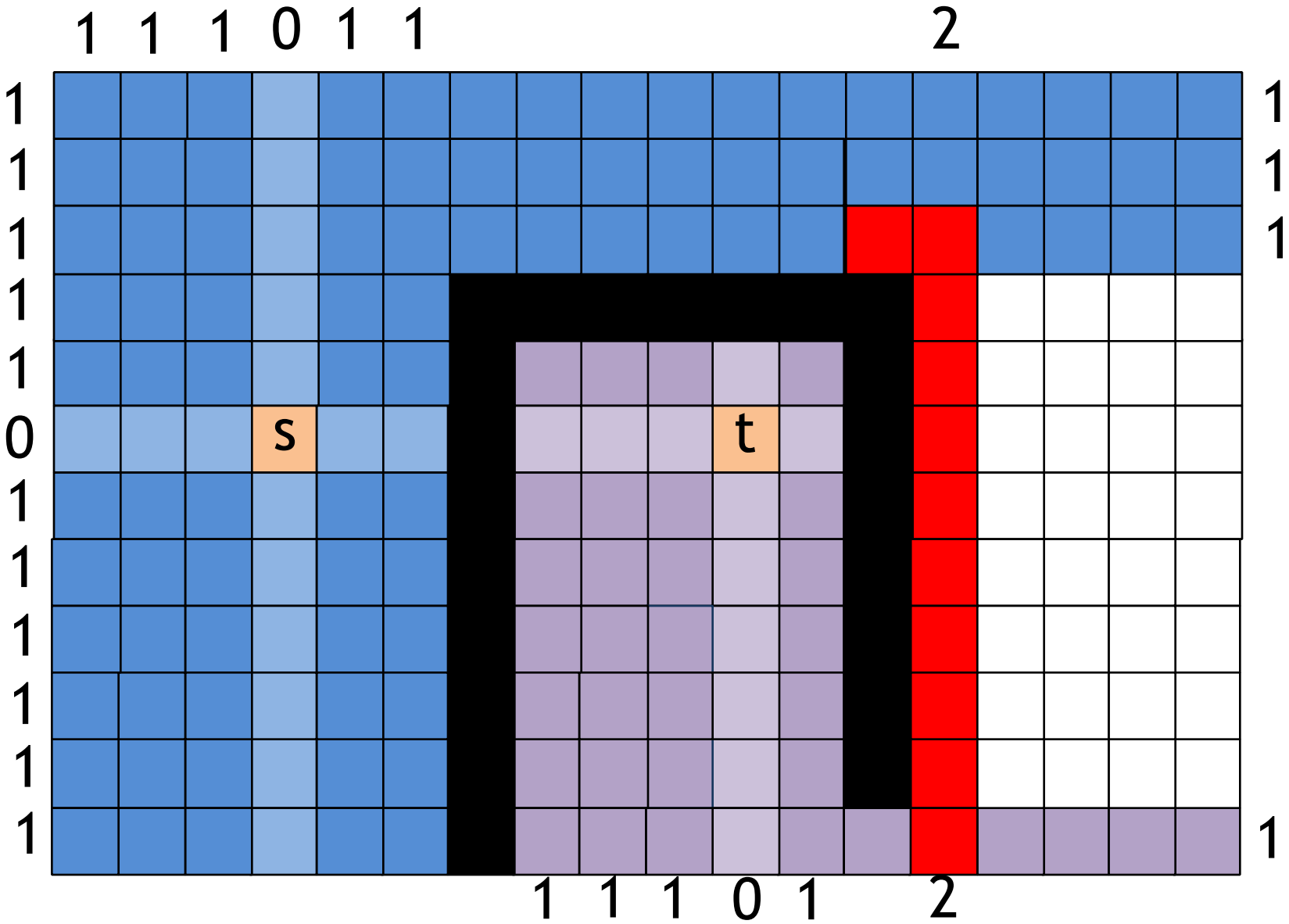
Backtrace Toward the Source



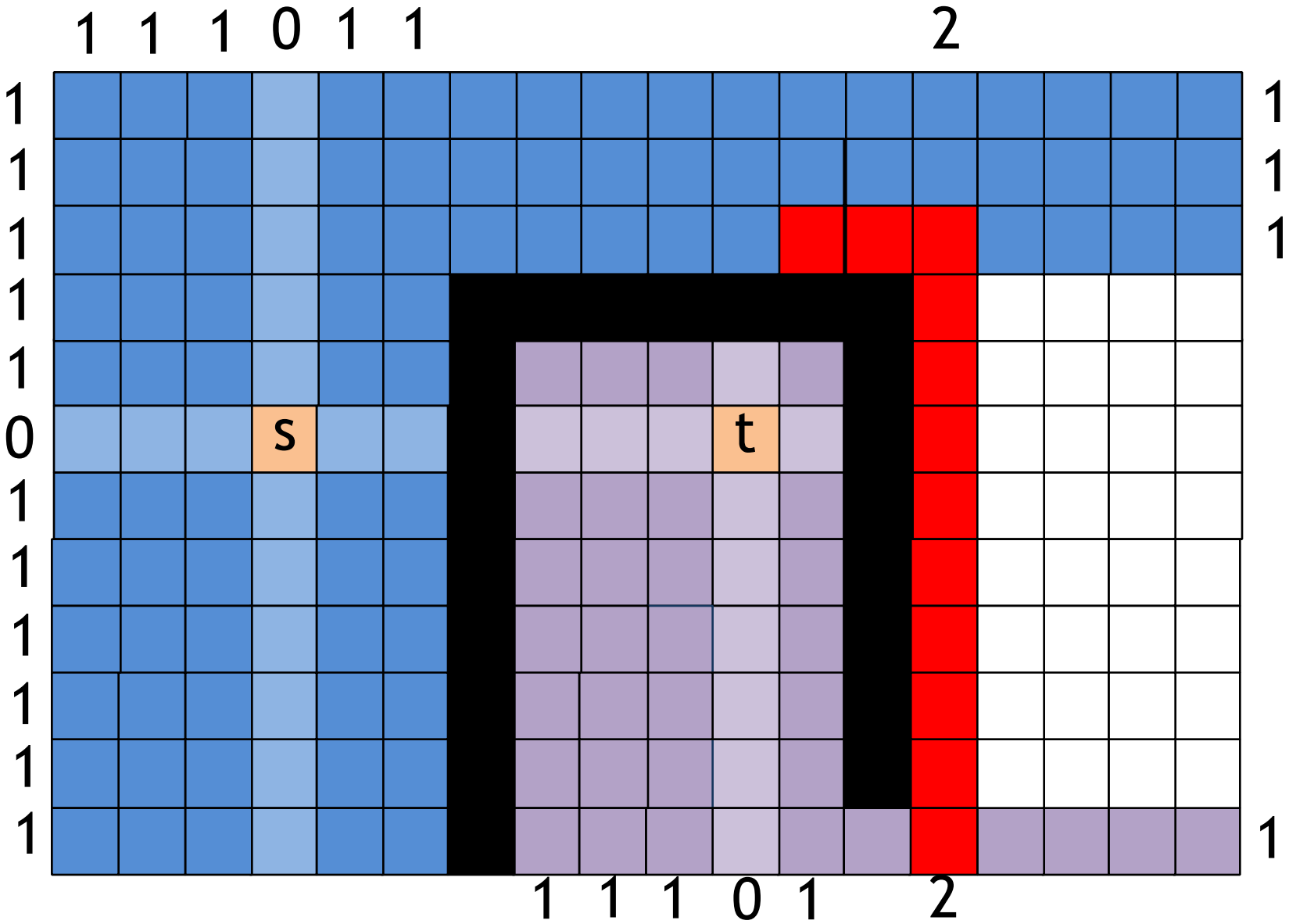
Follow the current line <u>backward</u> until you intersect with a line having a lower label

Follow the new line <u>backward</u>

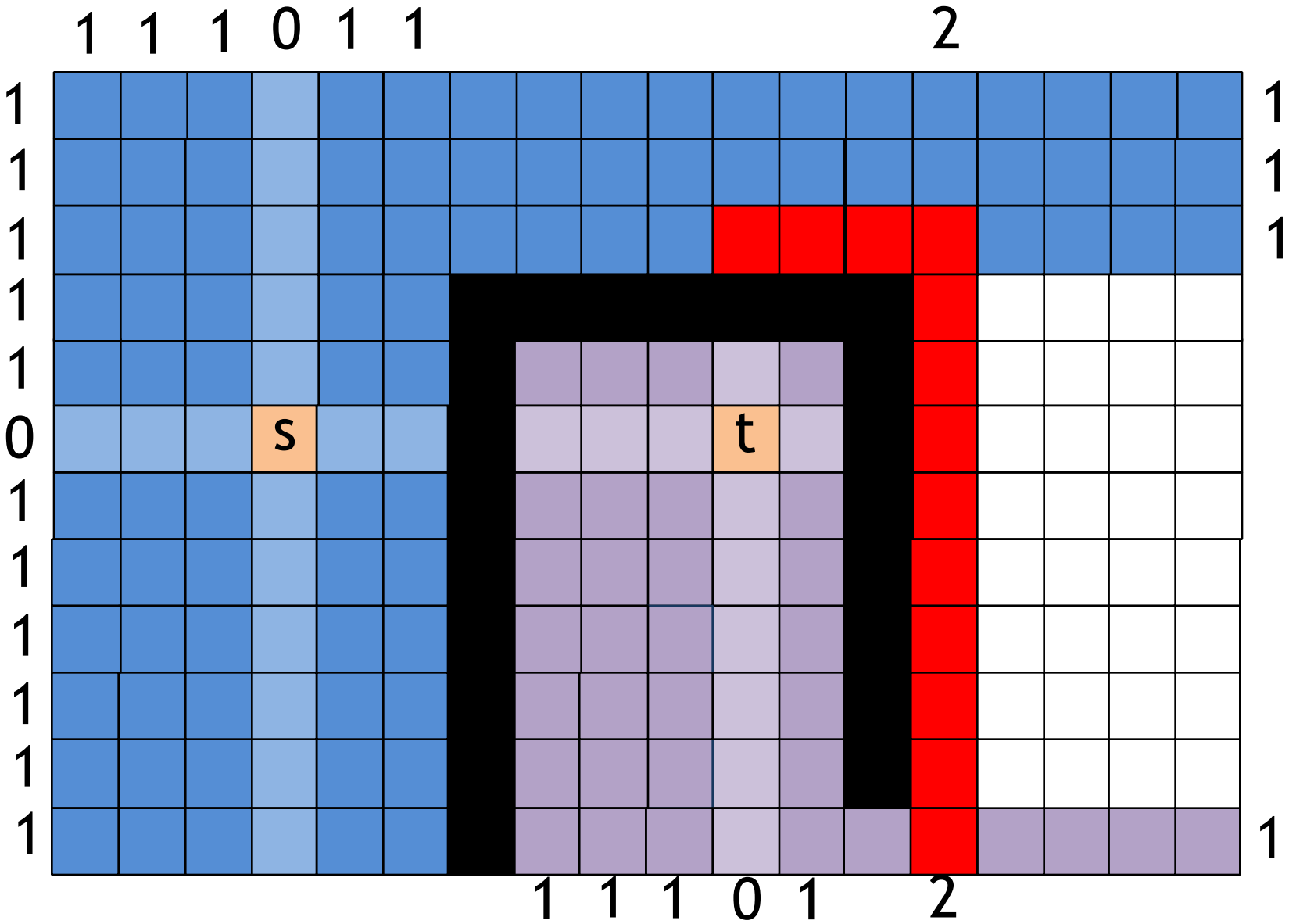
Backtrace Toward the Source



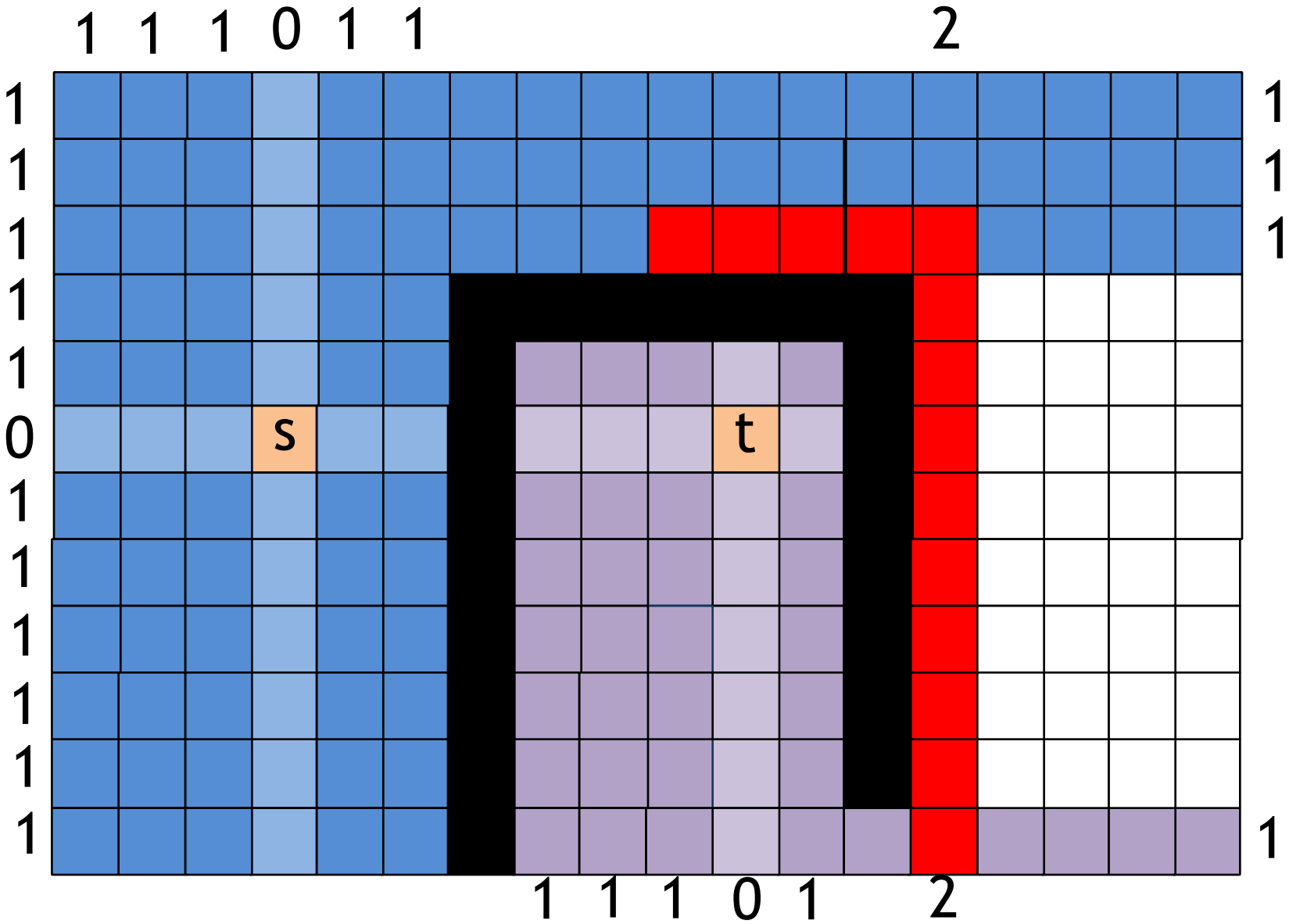
Backtrace Toward the Source



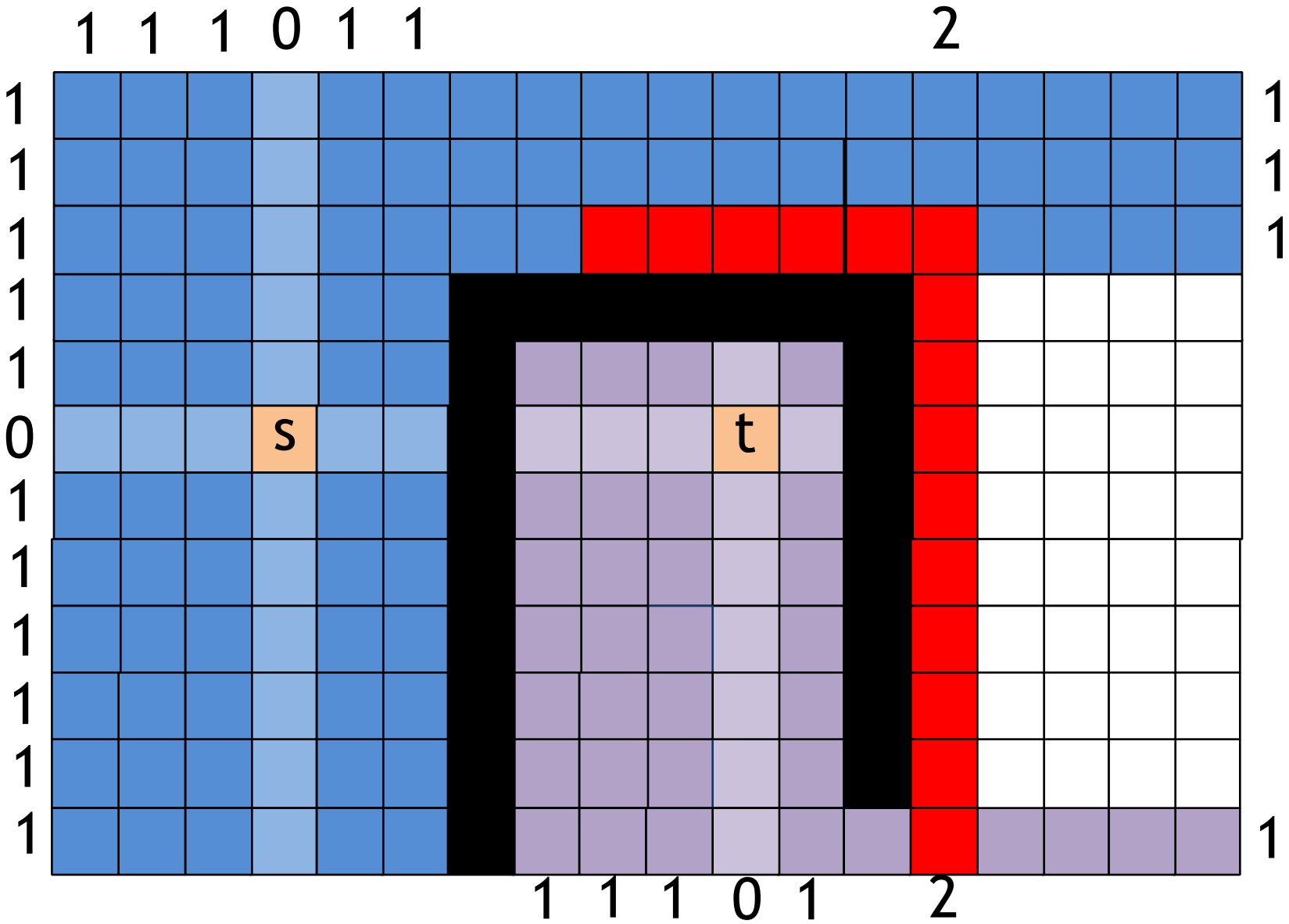
Backtrace Toward the Source



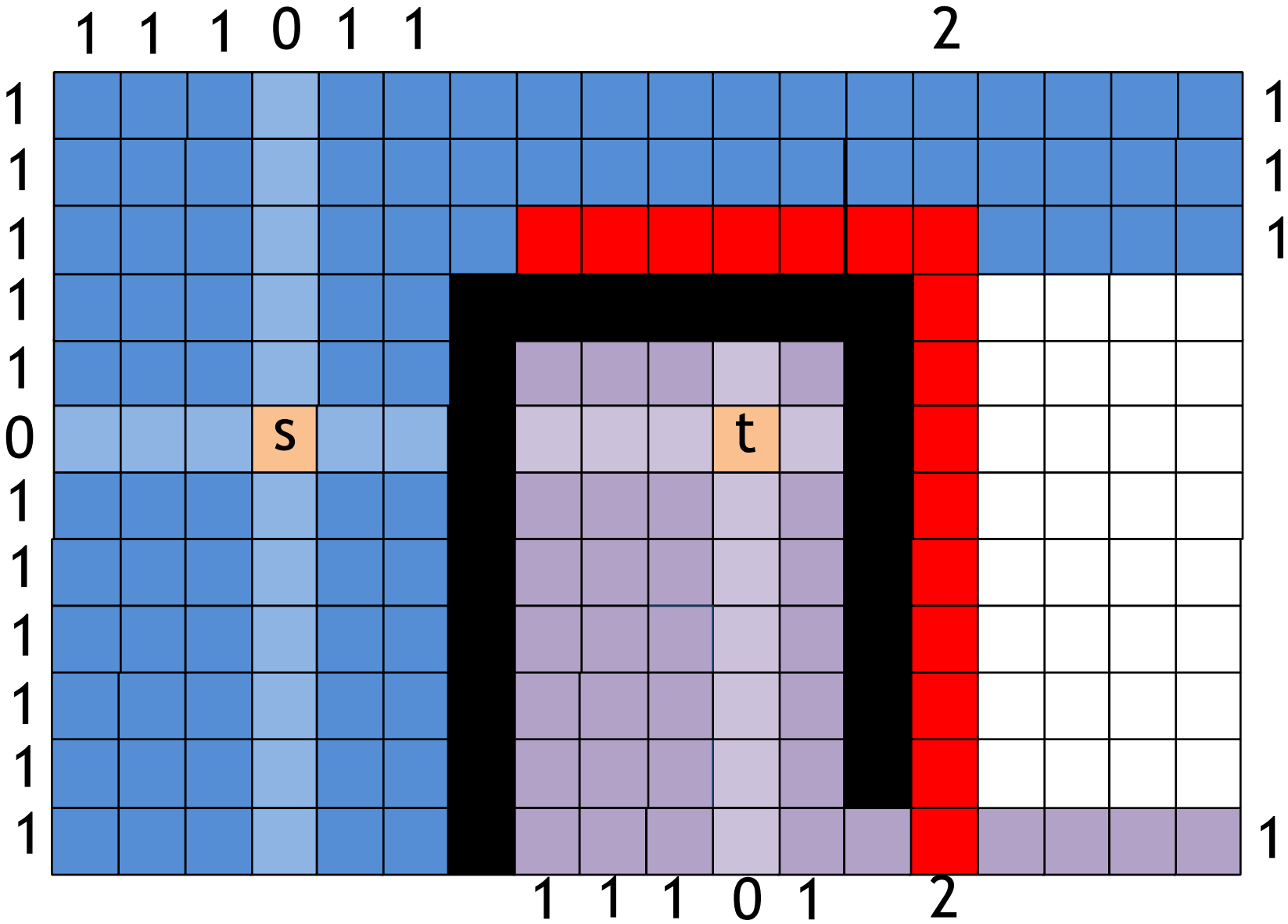
Backtrace Toward the Source



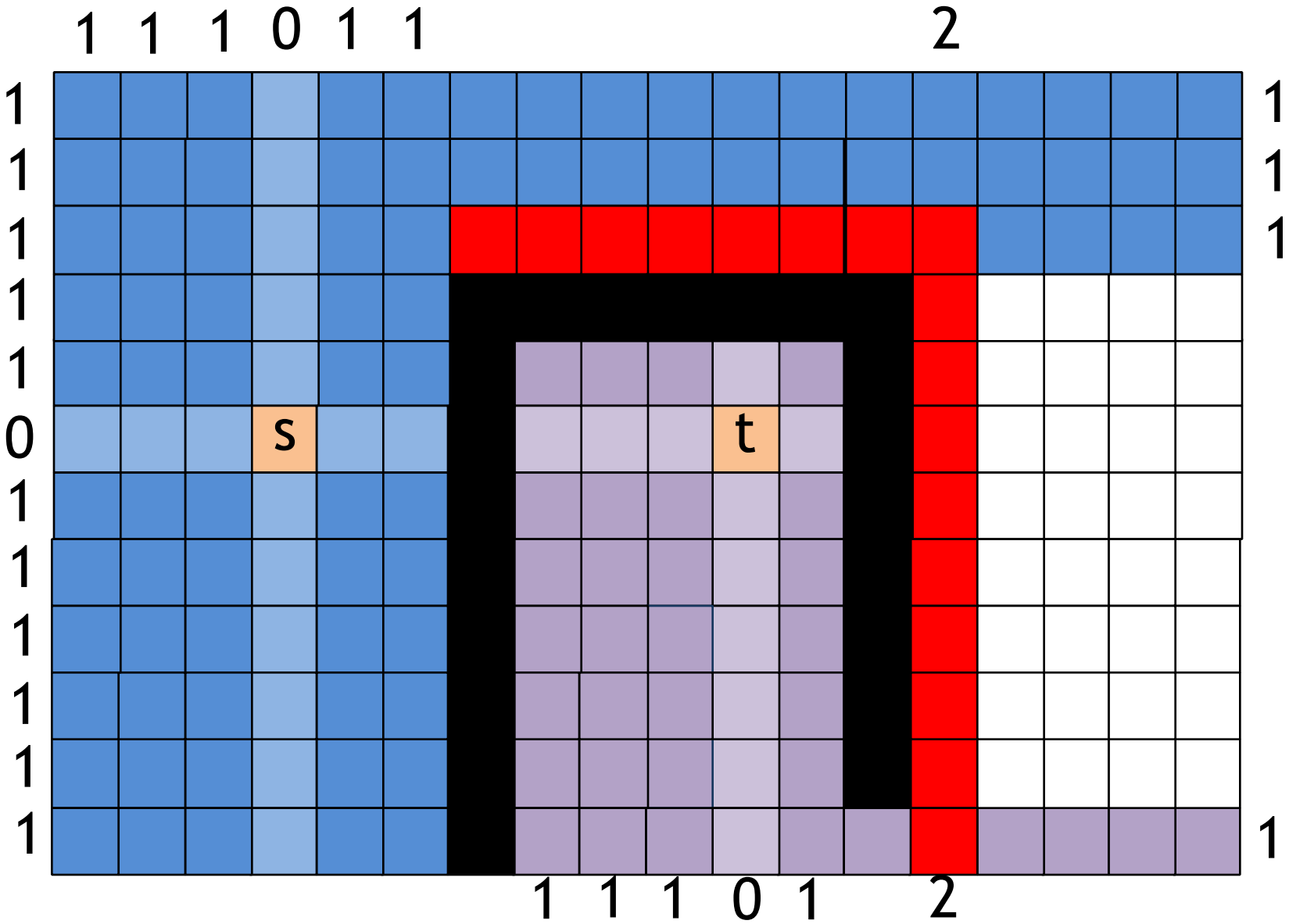
Backtrace Toward the Source



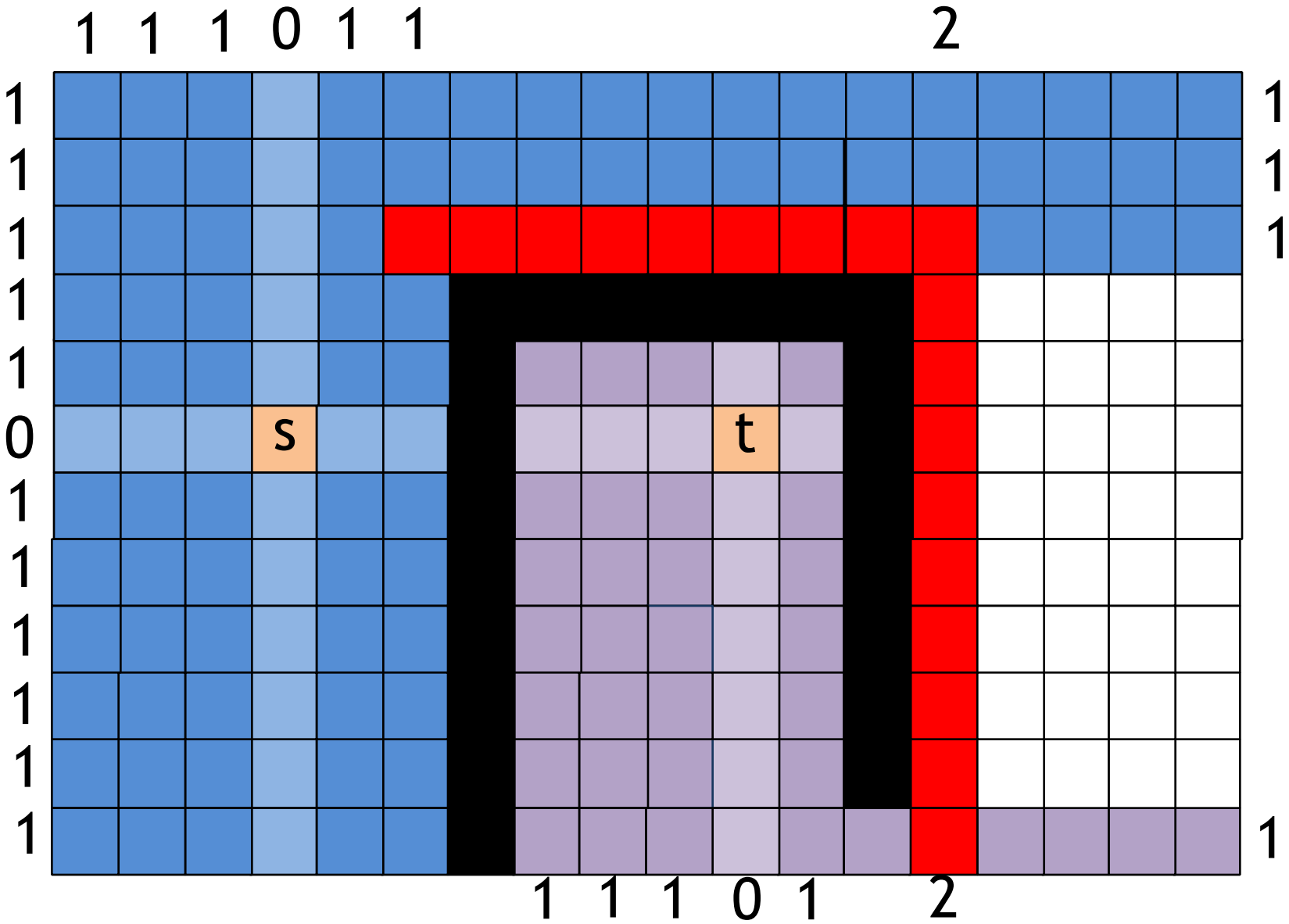
Backtrace Toward the Source



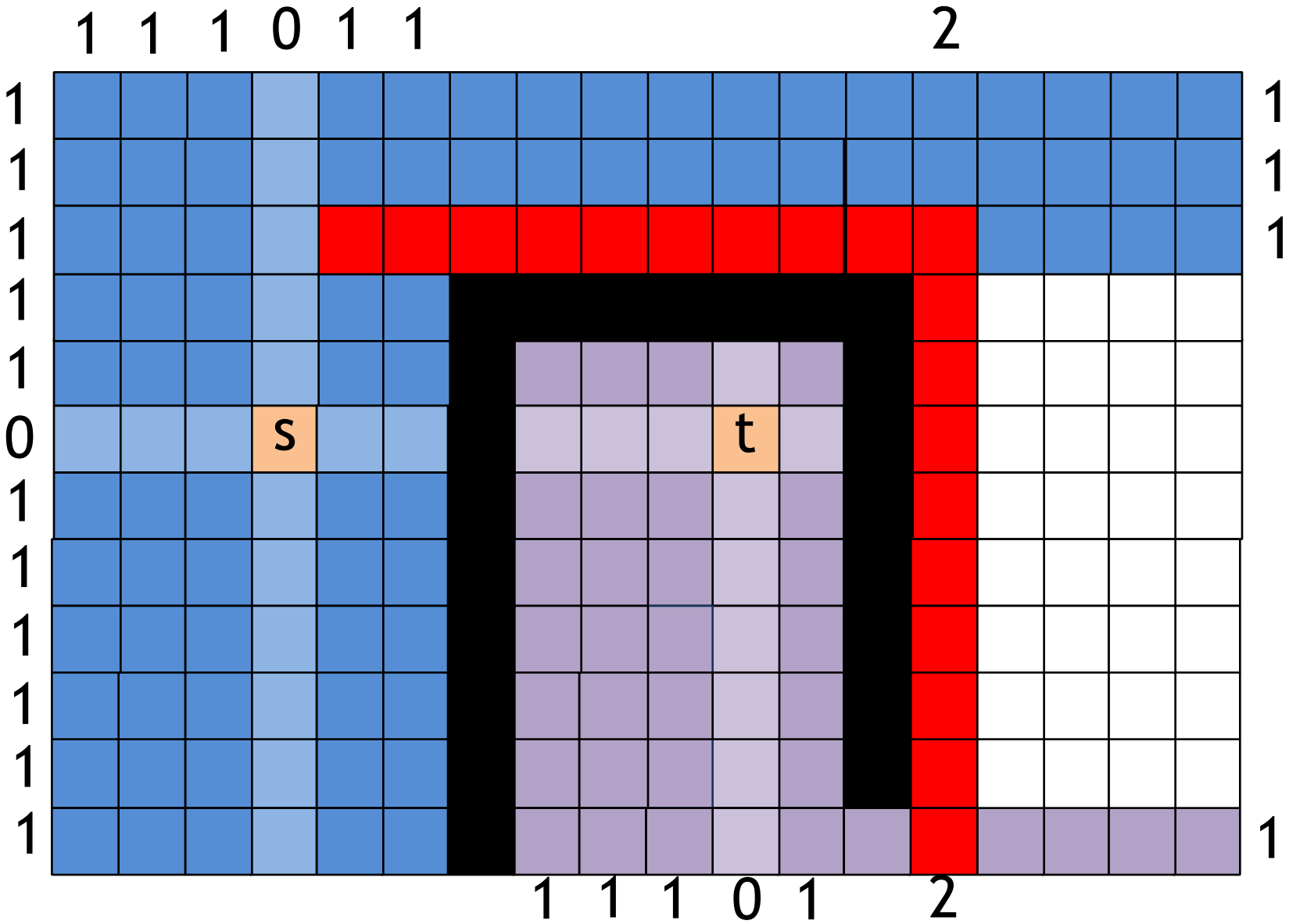
Backtrace Toward the Source



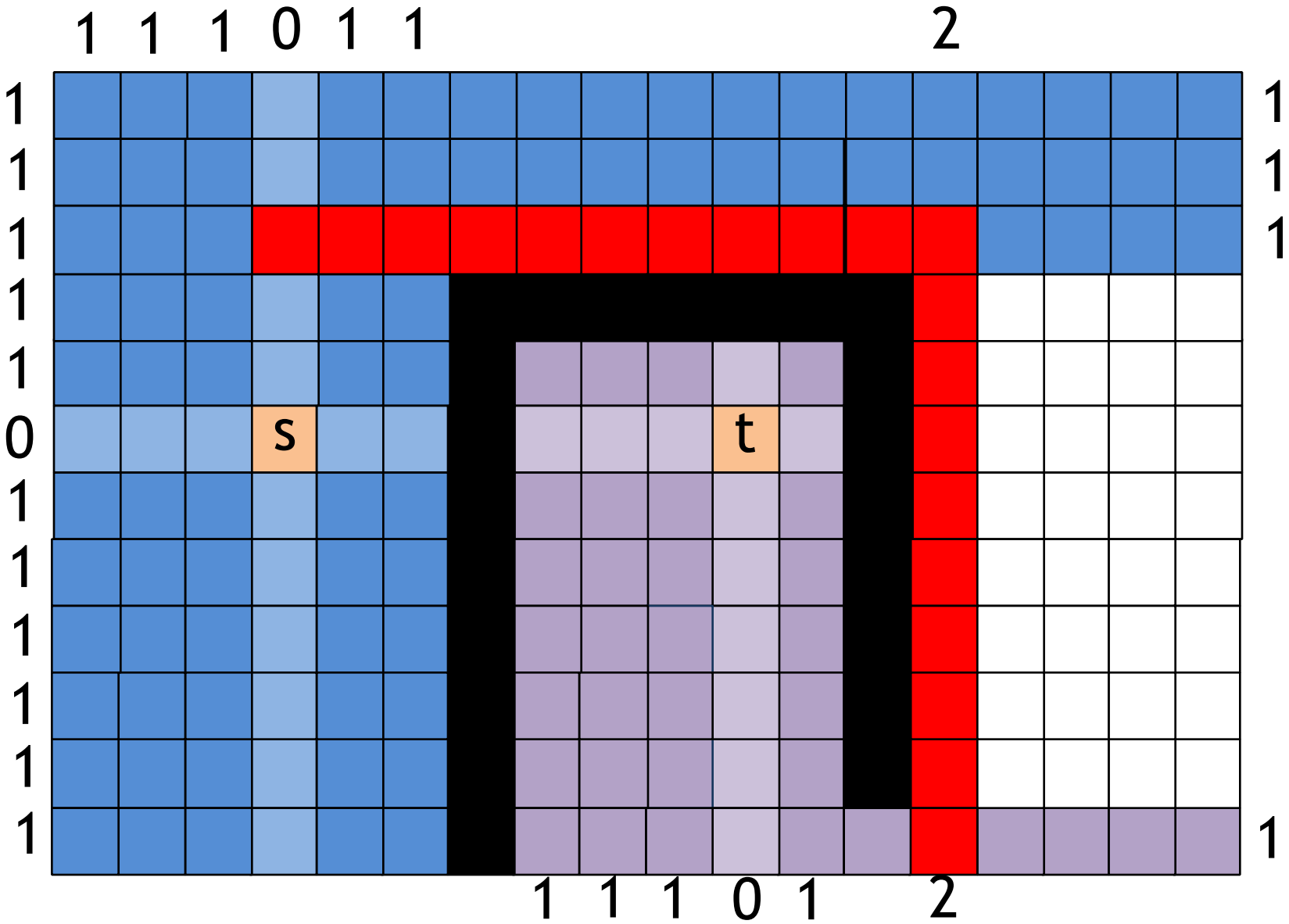
Backtrace Toward the Source



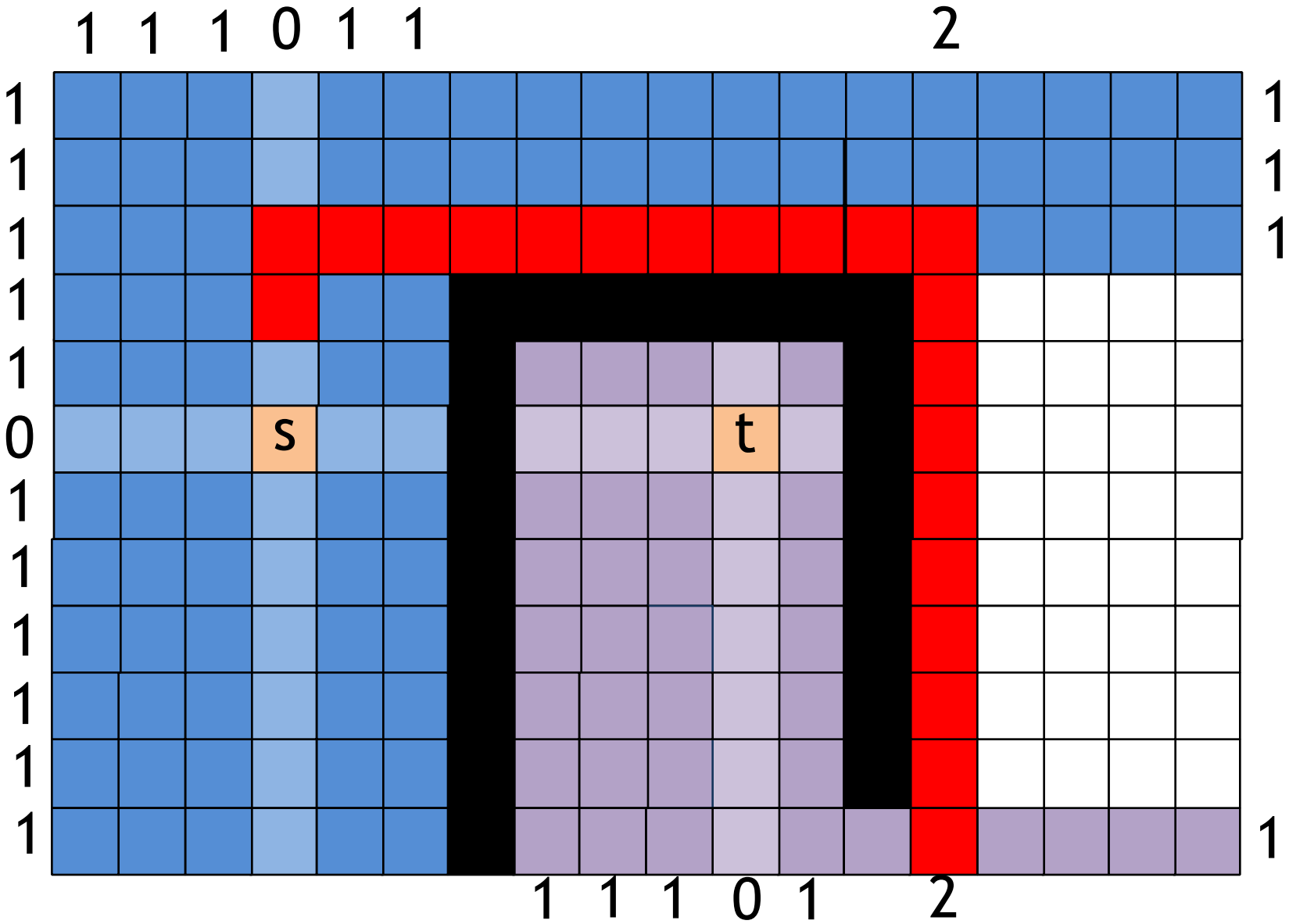
Backtrace Toward the Source



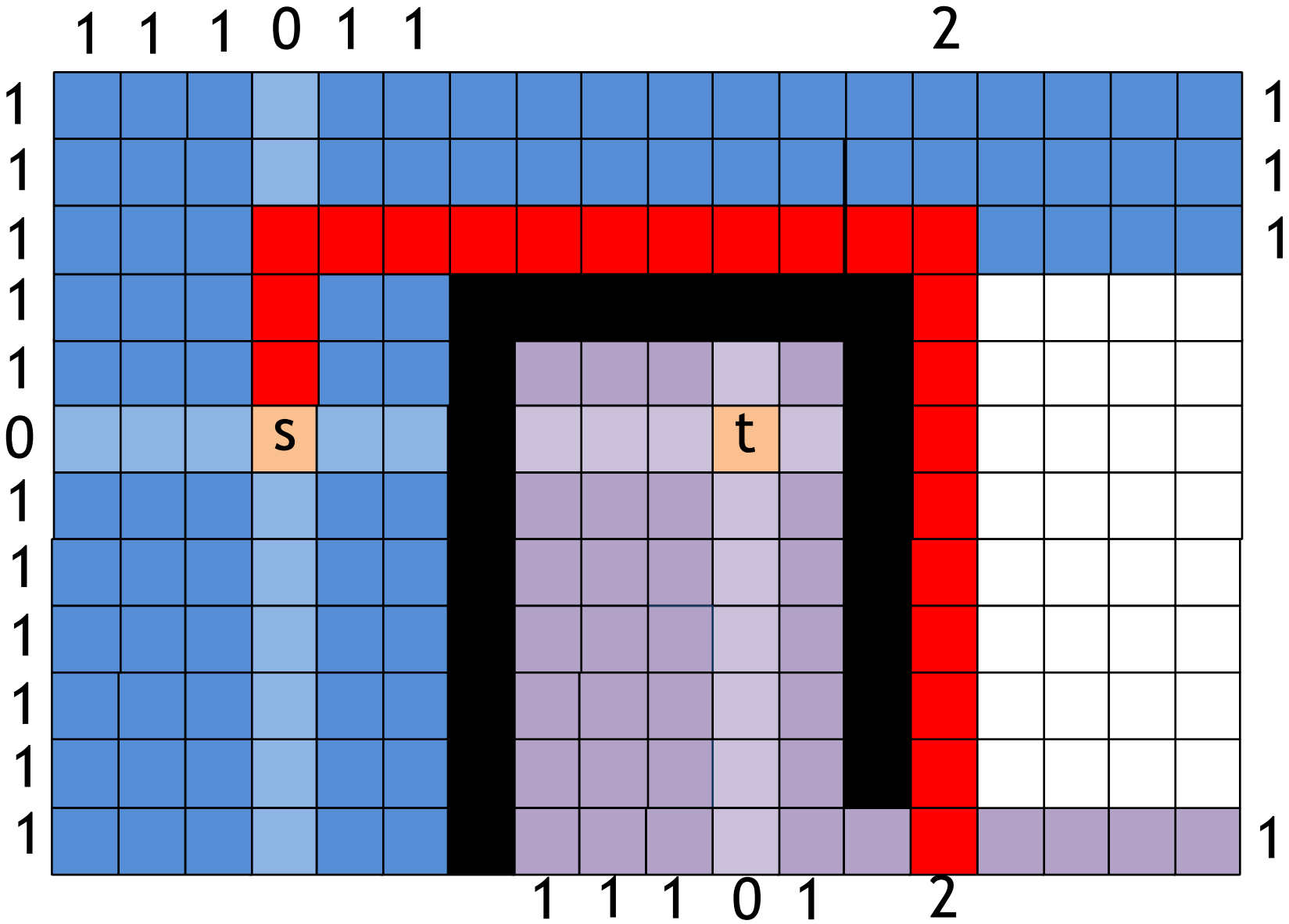
Backtrace Toward the Source



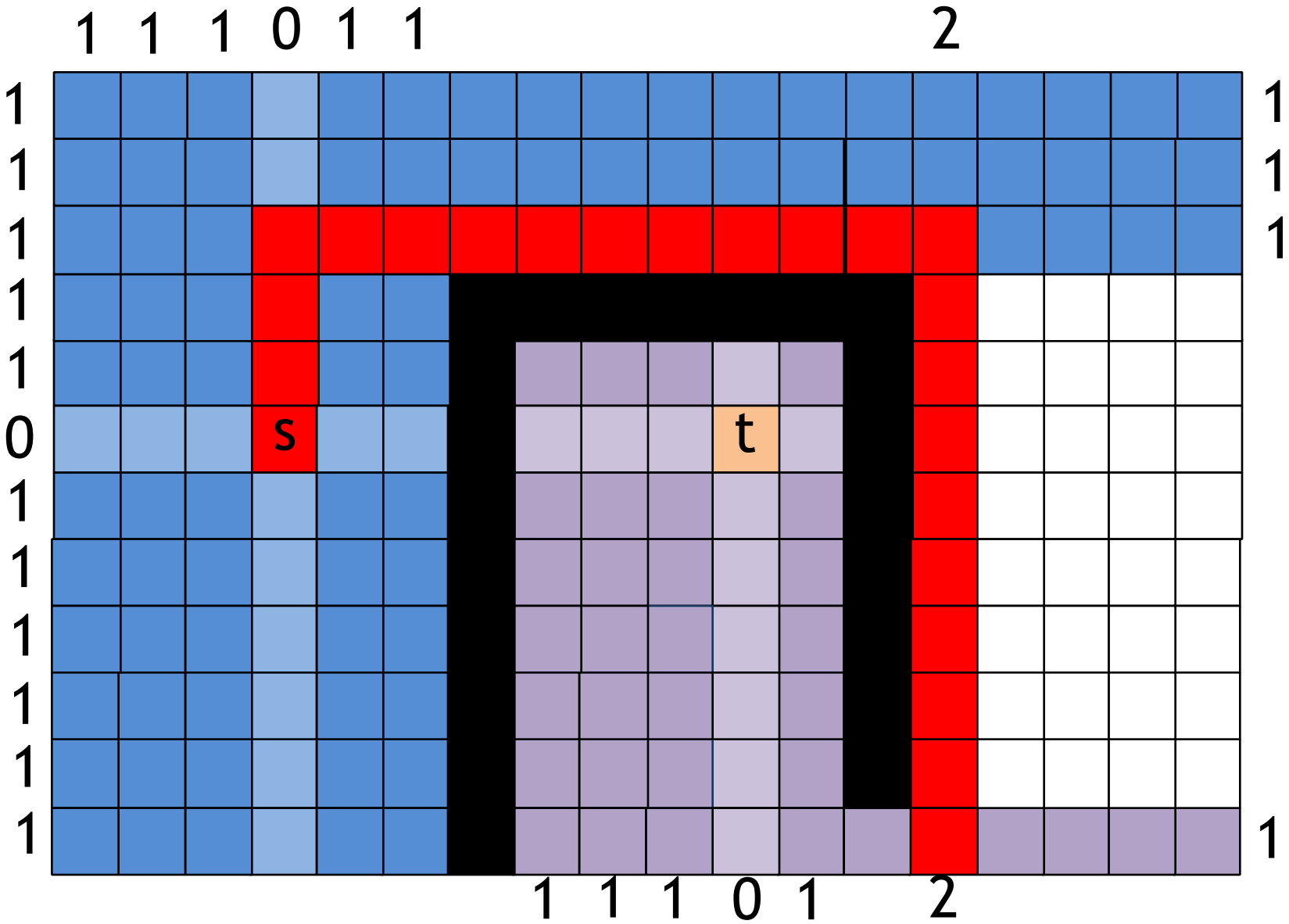
Backtrace Toward the Source



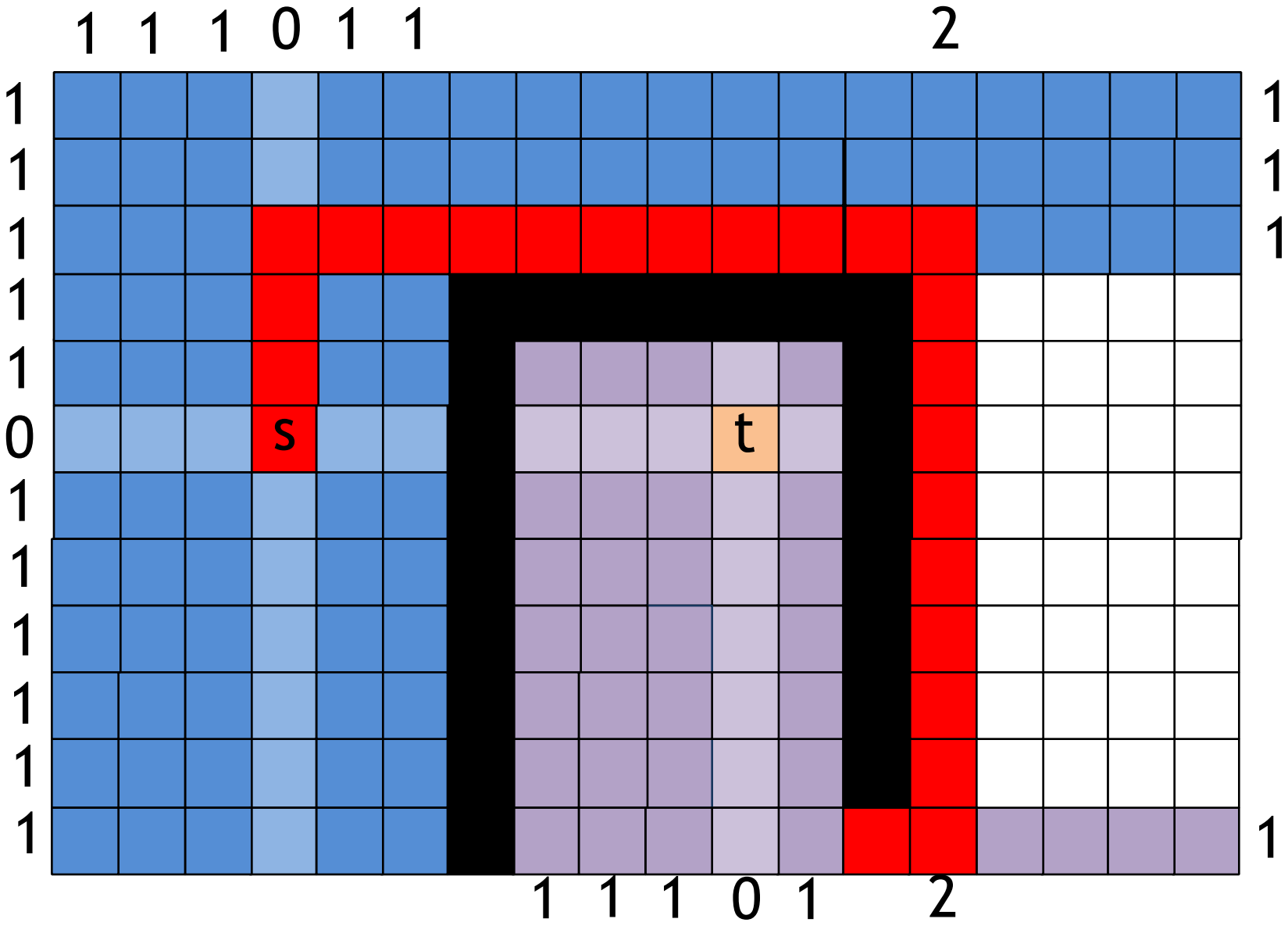
Backtrace Toward the Source



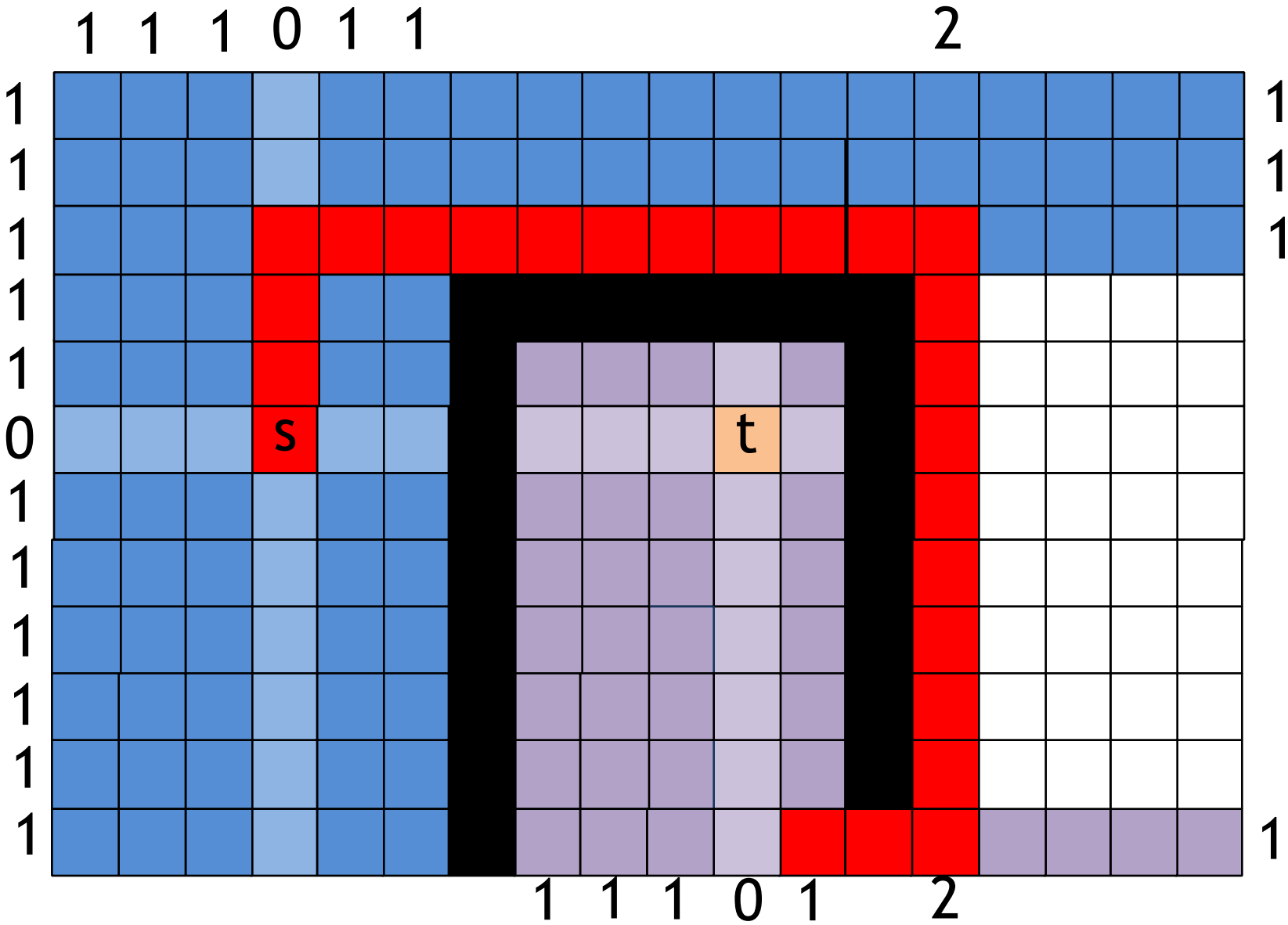
Backtrace Toward the Source



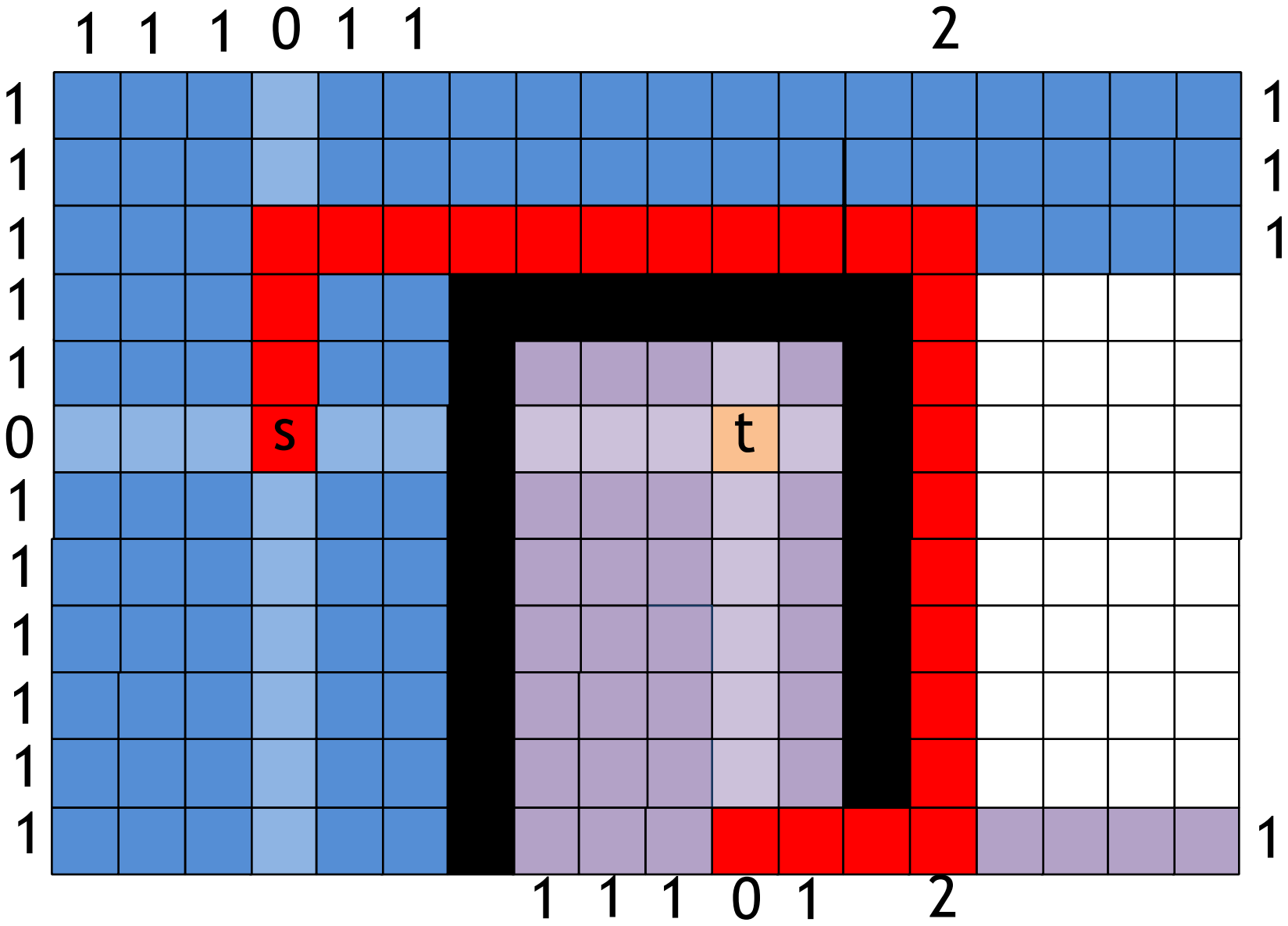
Backtrace Toward the Sink



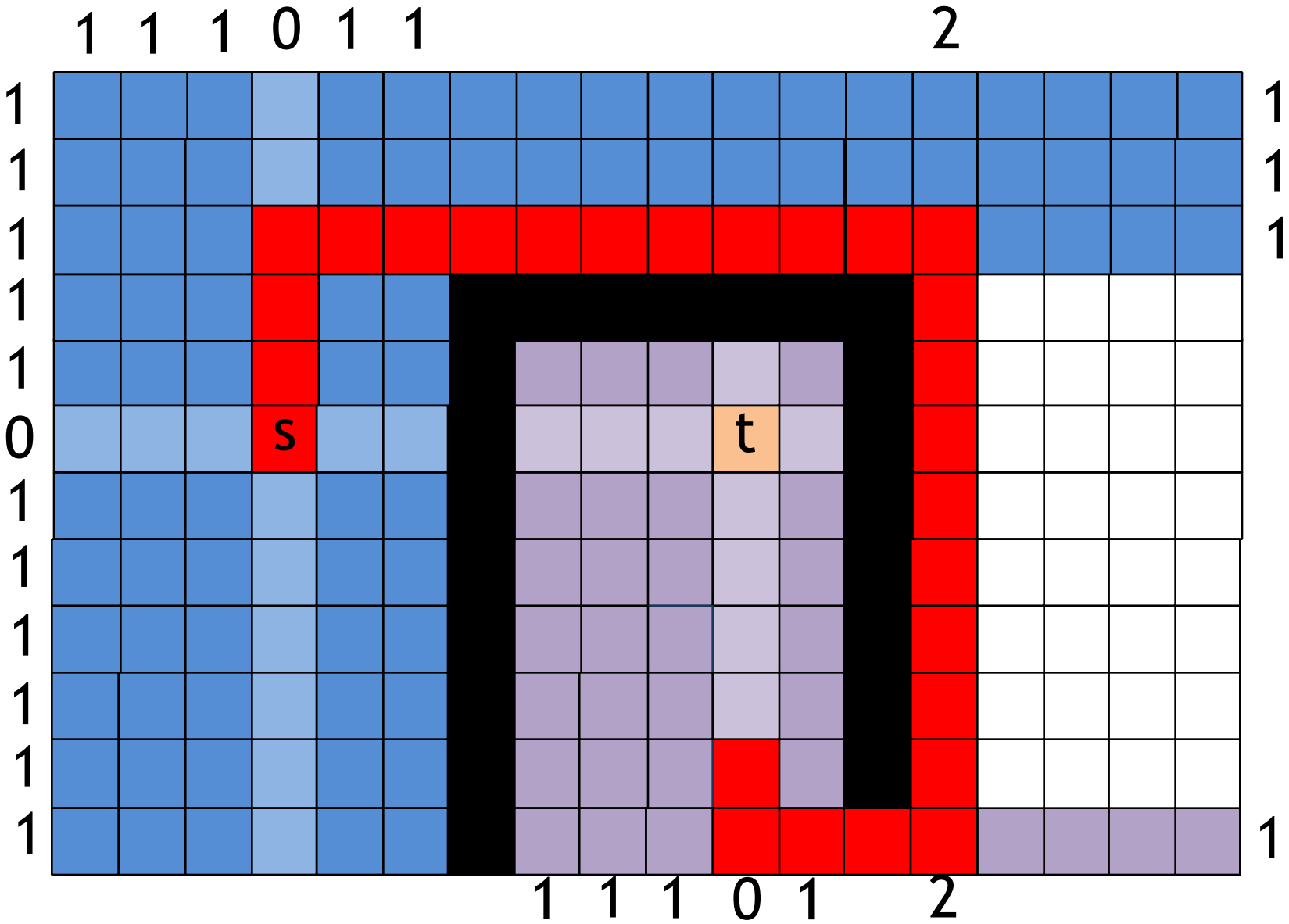
Backtrace Toward the Sink



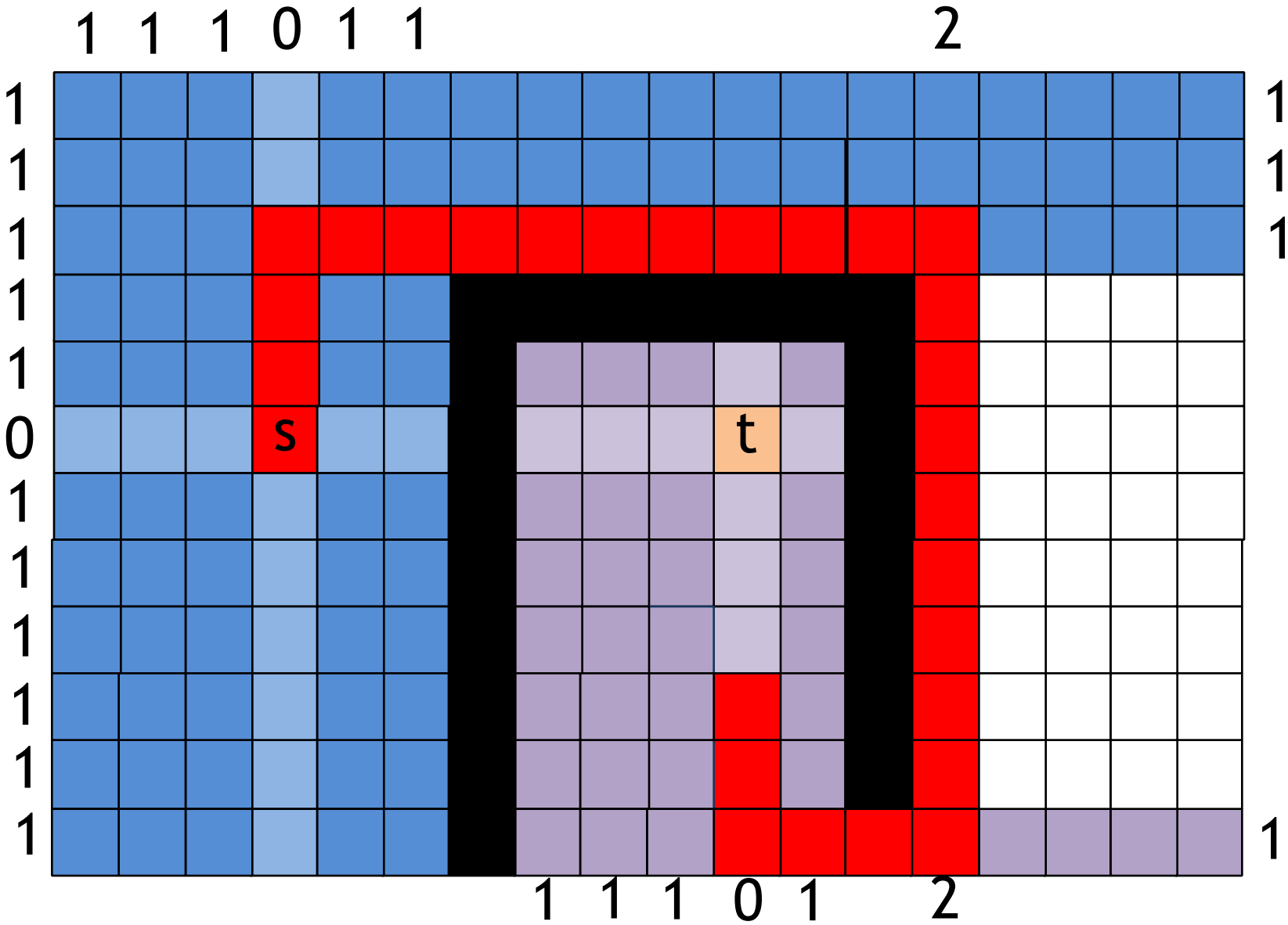
Backtrace Toward the Sink



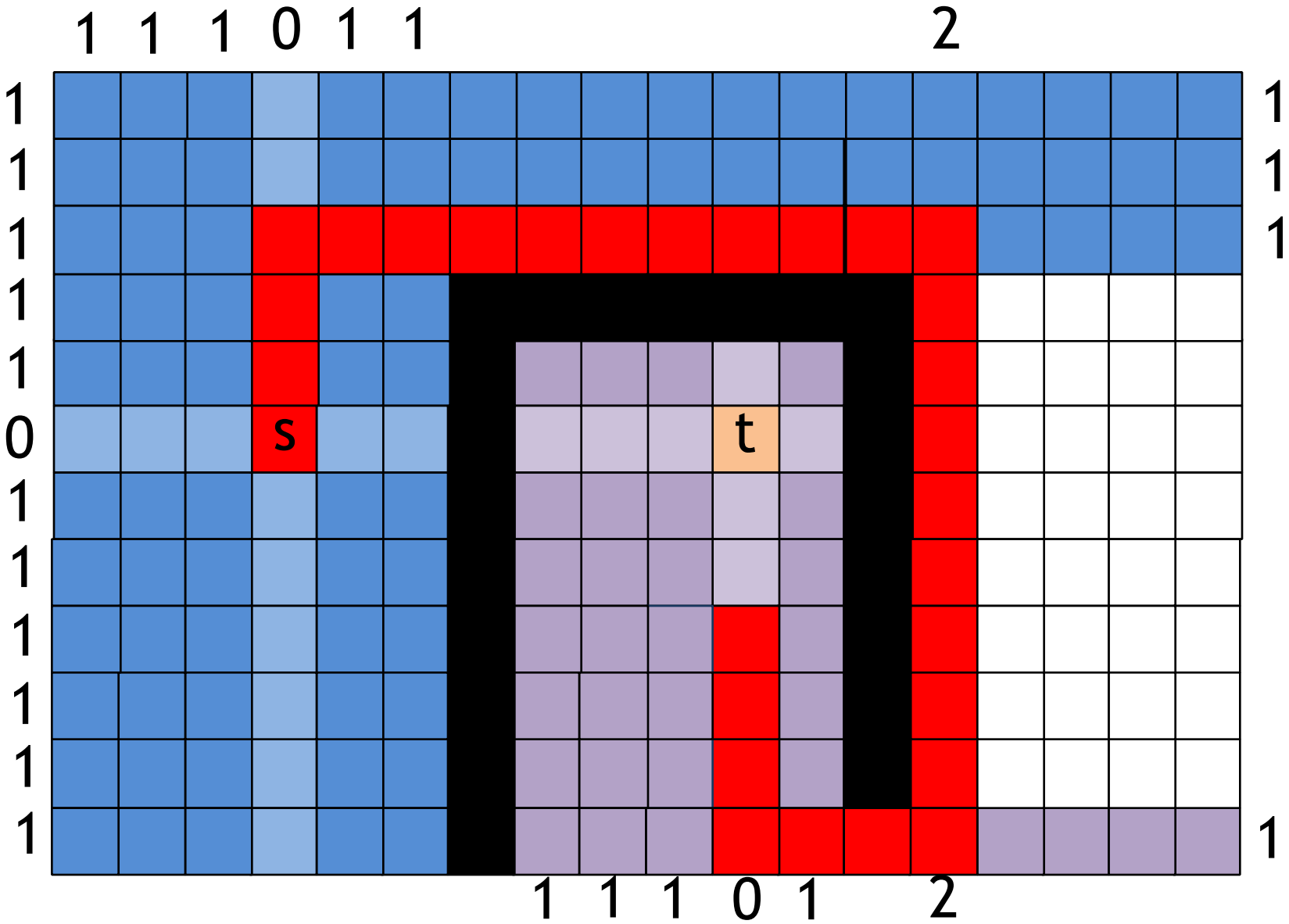
Backtrace Toward the Sink



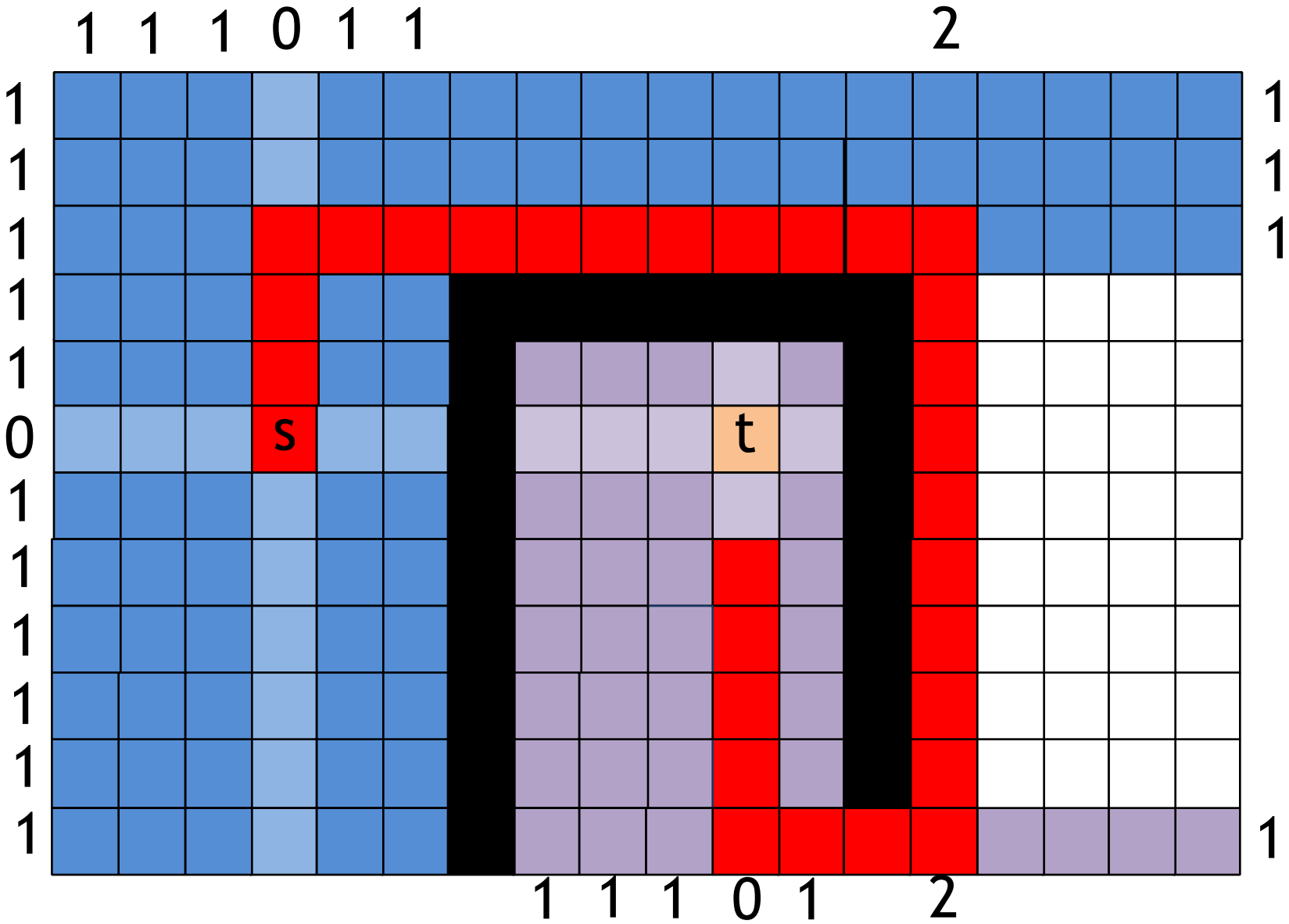
Backtrace Toward the Sink



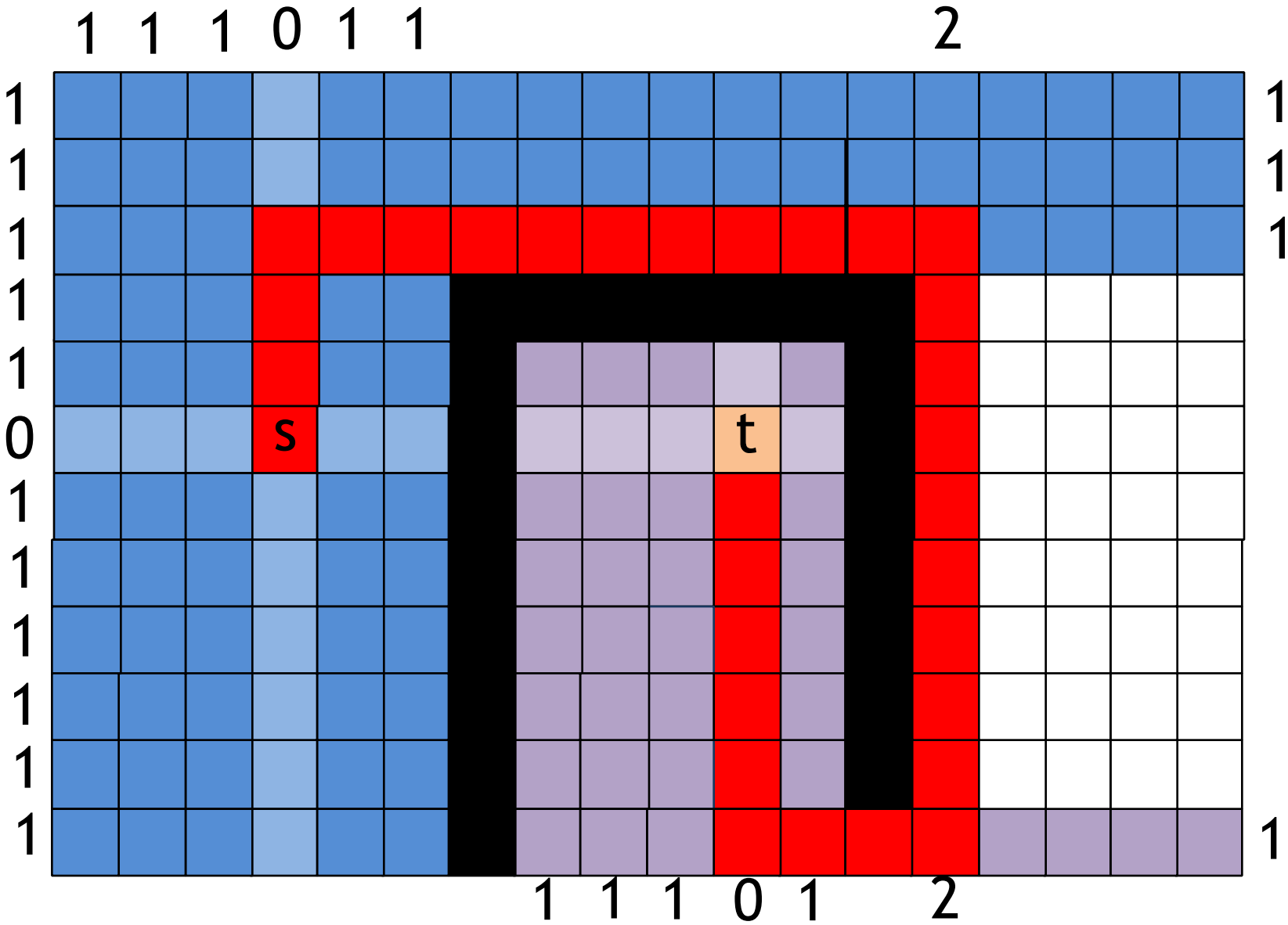
Backtrace Toward the Sink



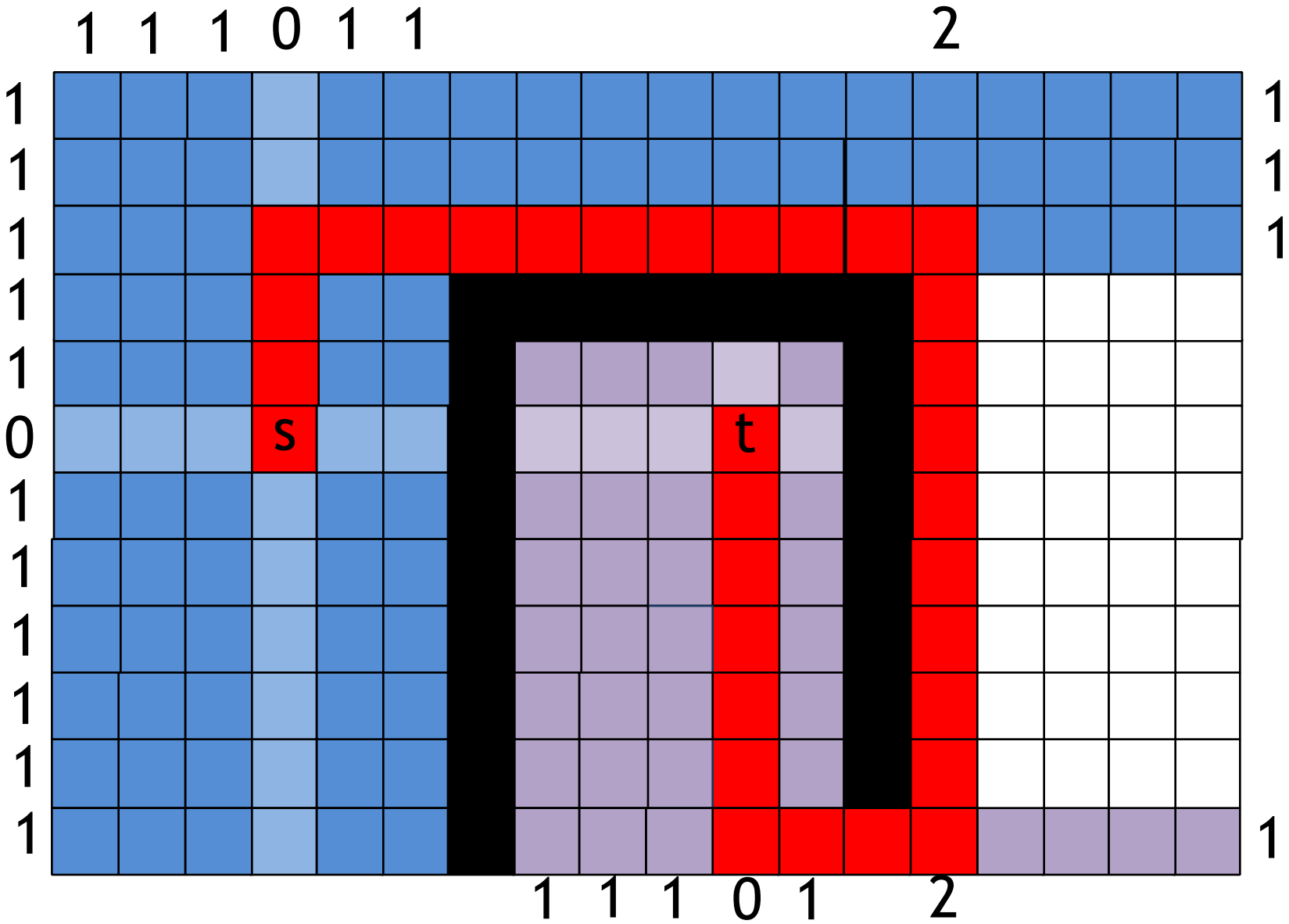
Backtrace Toward the Sink



Backtrace Toward the Sink



Backtrace Toward the Sink



Not to Belabor the Obvious

- That was rather inefficient…

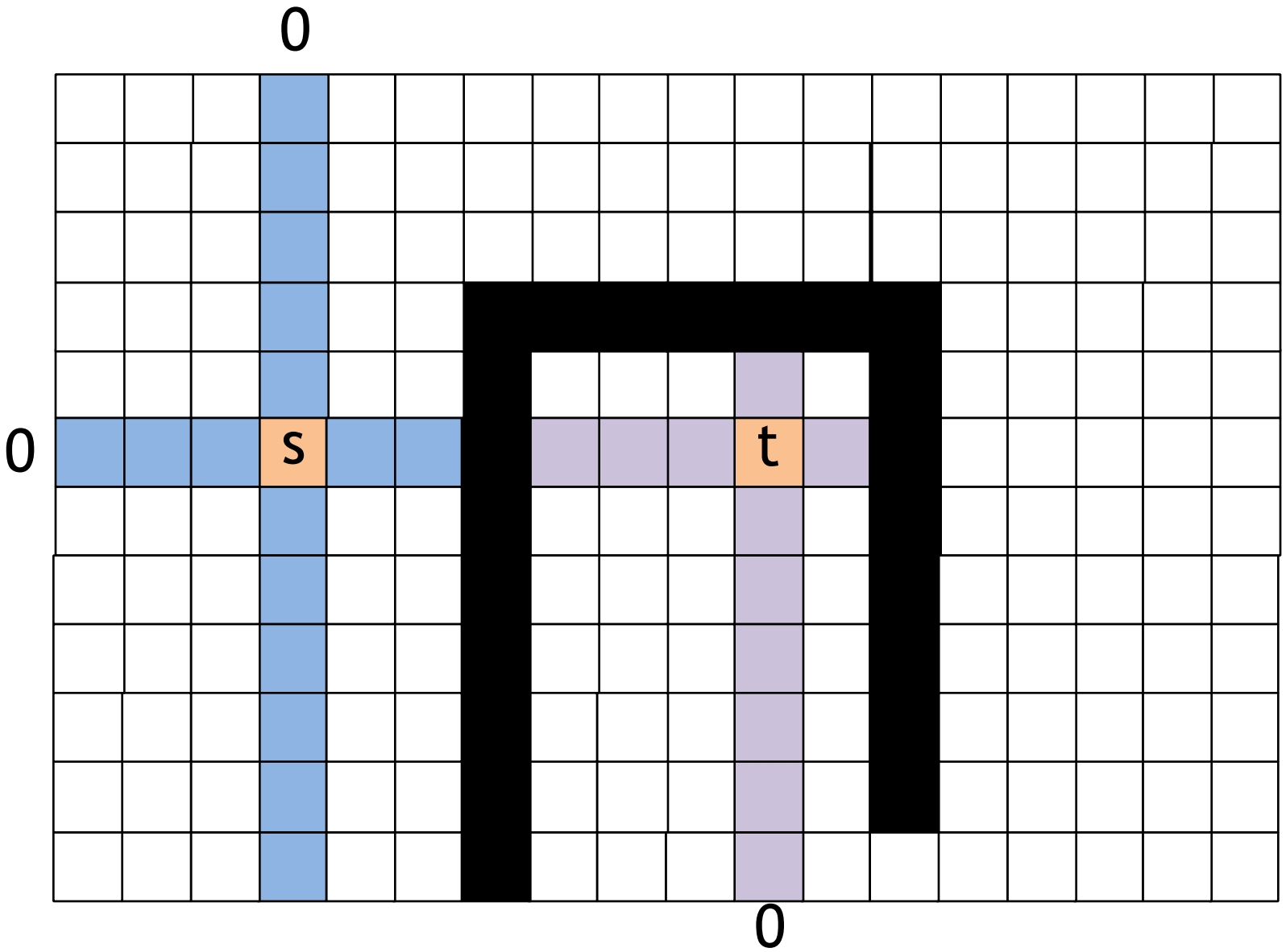
Hightower's Algorithm

- Hightower, D. (1969), *A Solution to the Line Routing Problem on the Continuous Plane*, Proceedings of the Design Automation Conference (DAC), 1-24

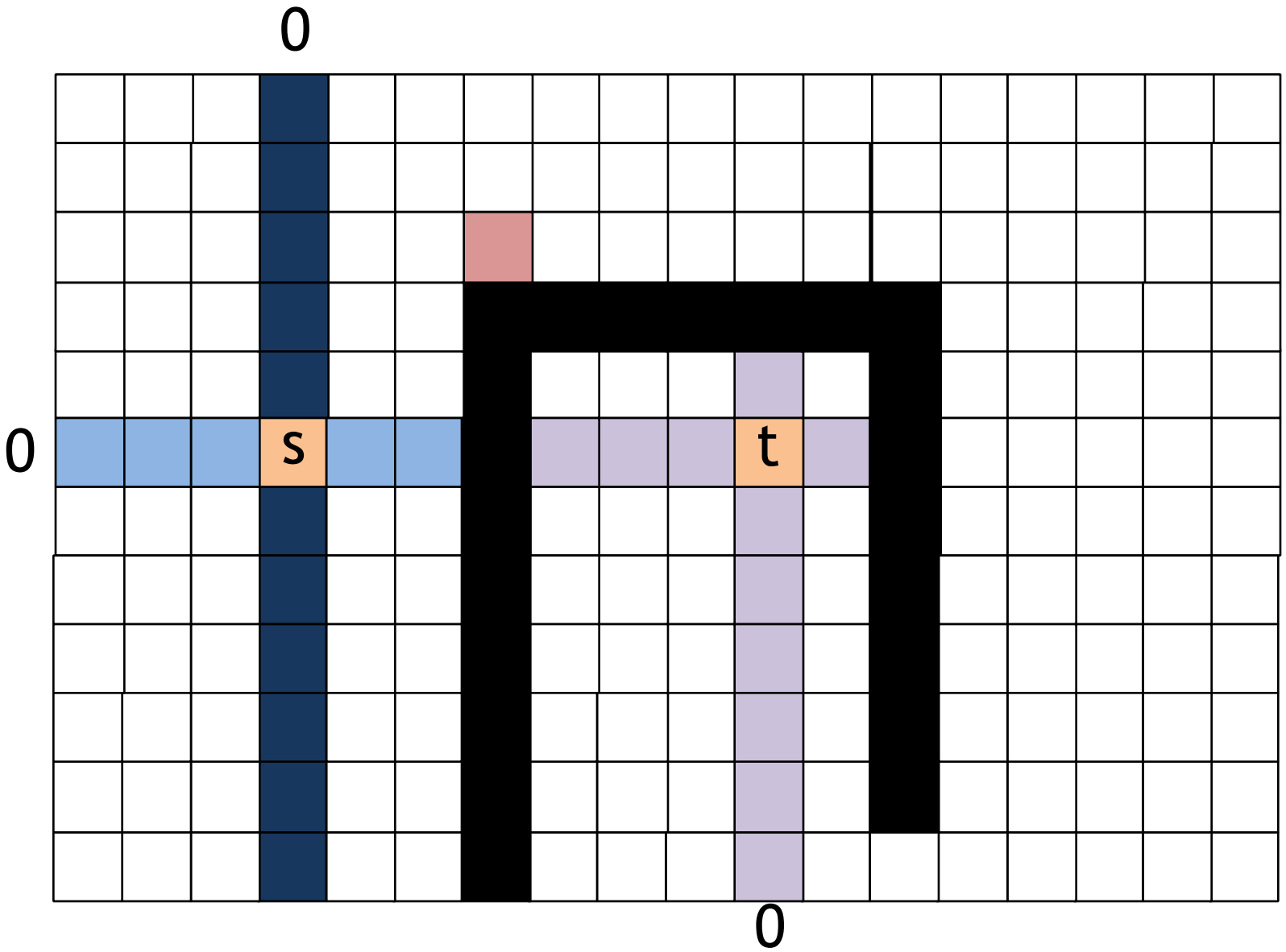
Hightower's Algorithm

- One escape point per line segment
- If a line runs parallel to a segment of blocked cells, place the escape point just past the endpoint of the segment

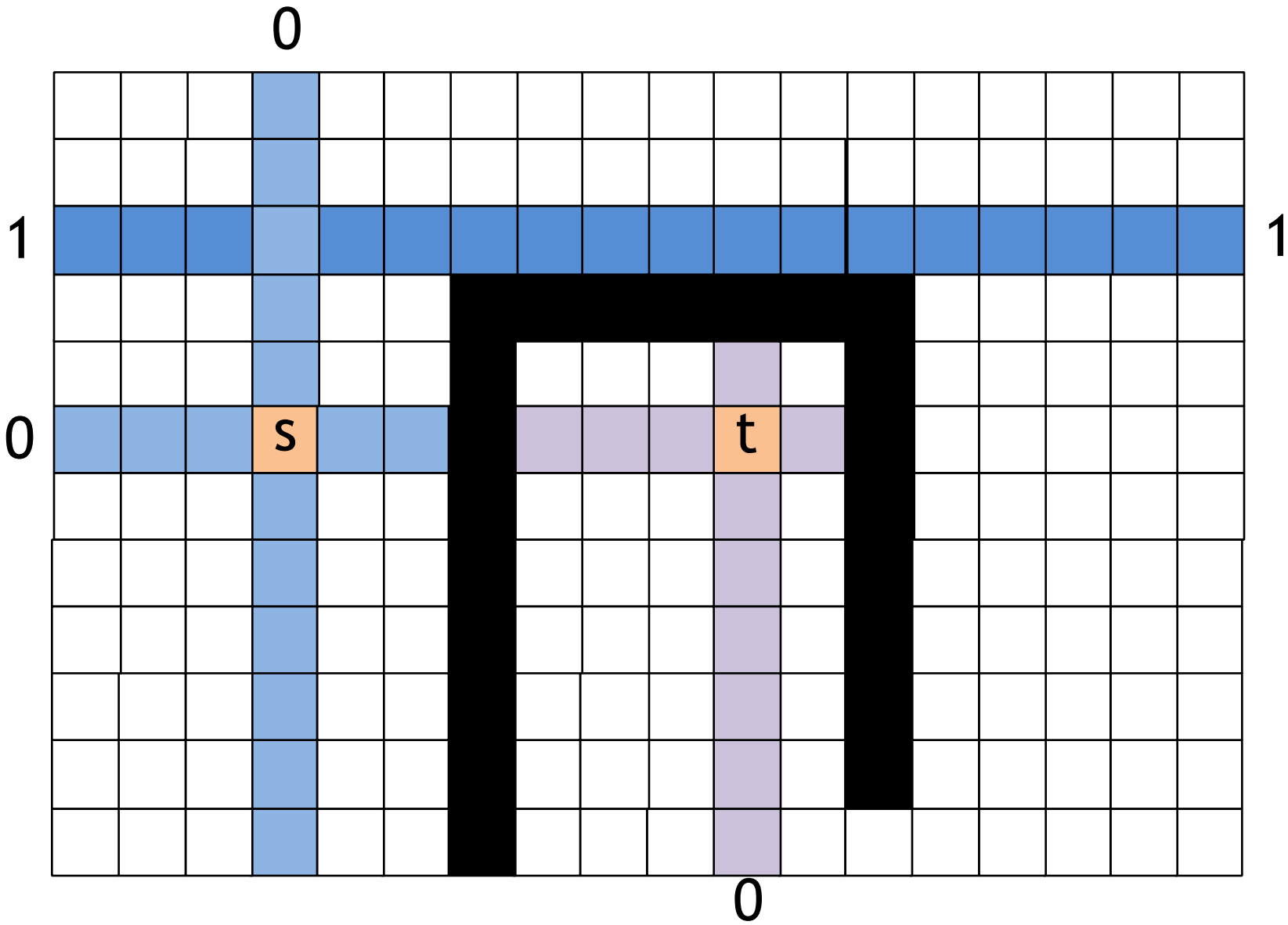
Source and Sink Line Probes (Level 0)



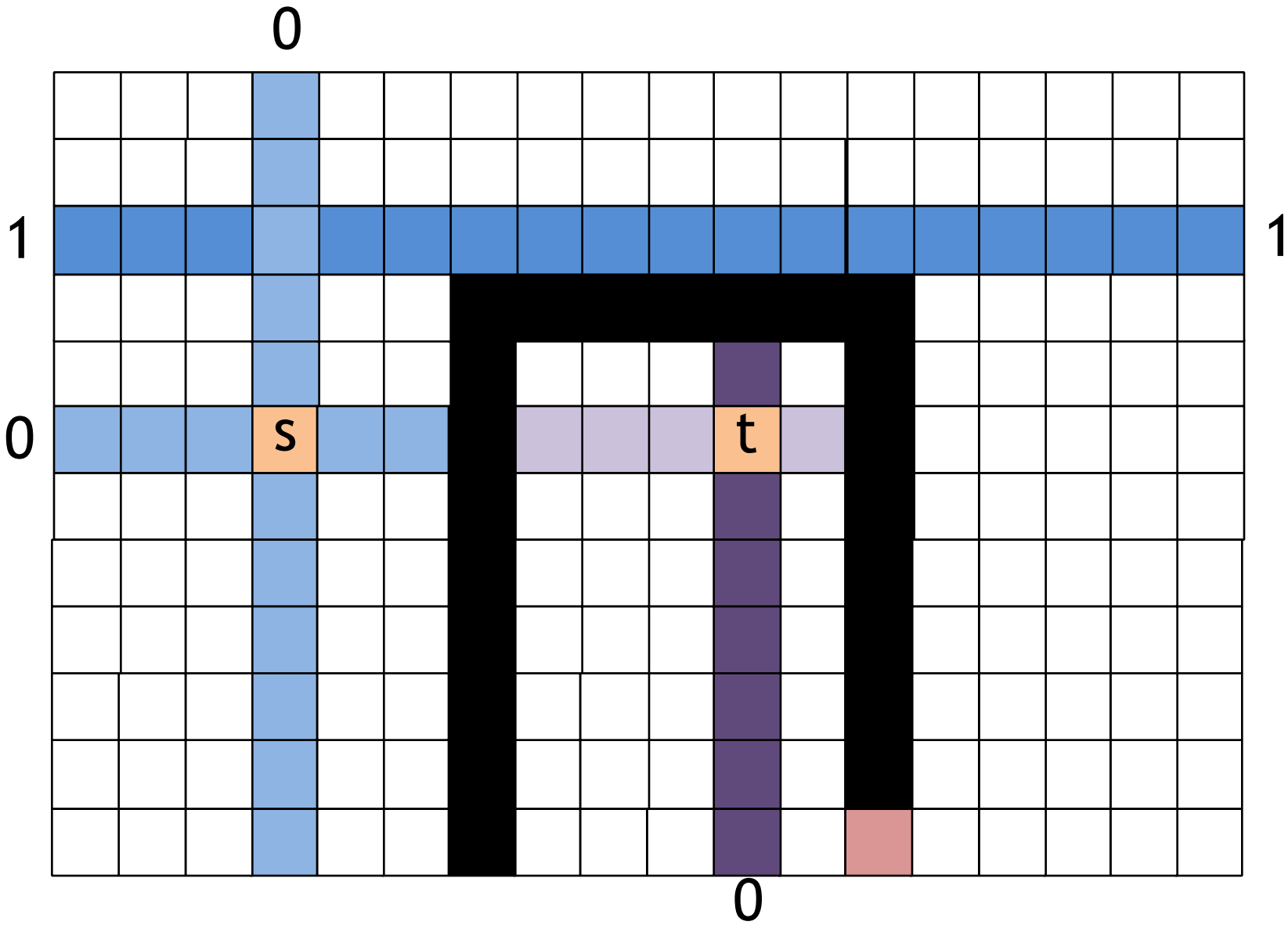
Source Line Probe (Level 1)



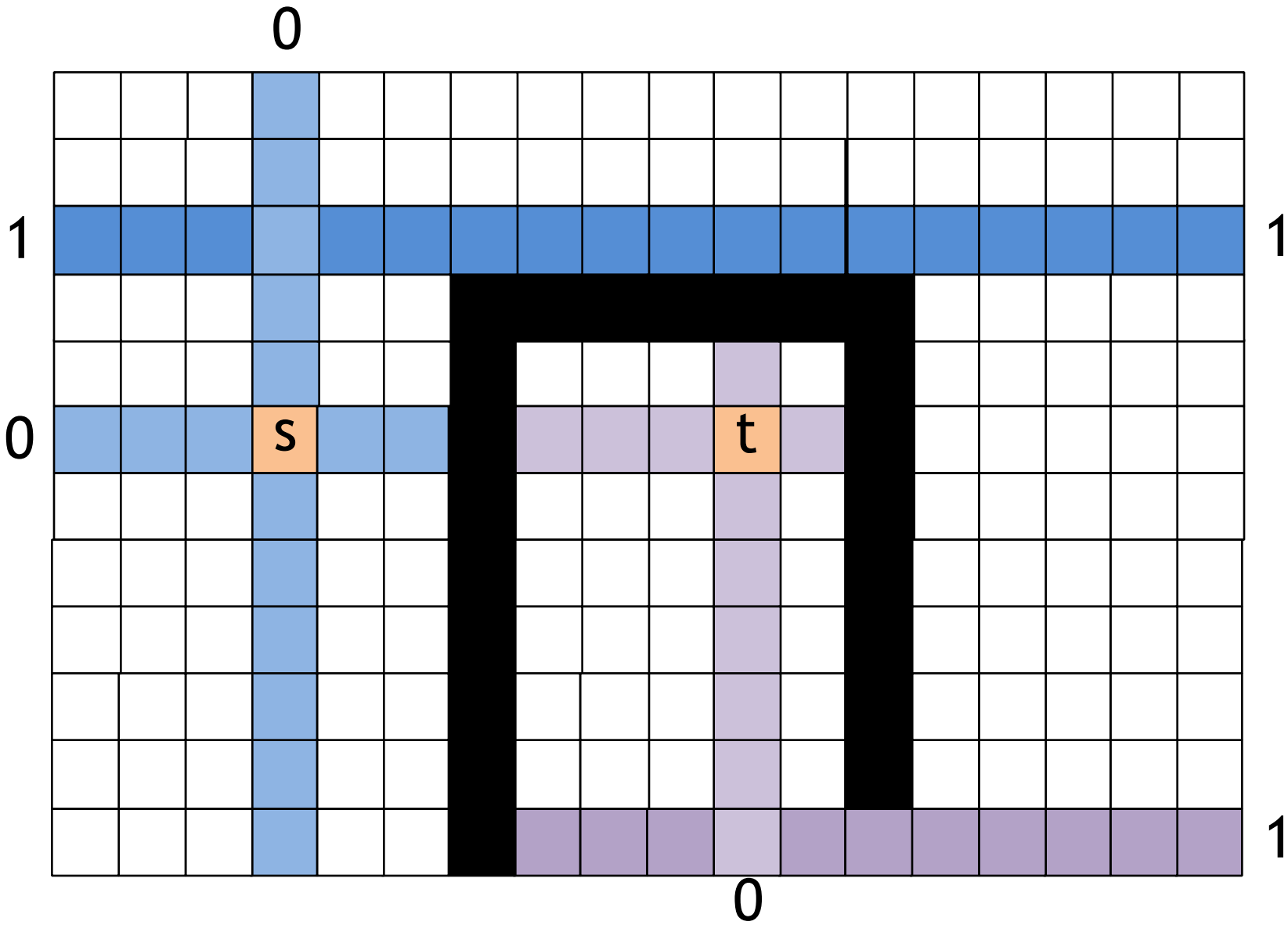
Source Line Probe (Level 1)



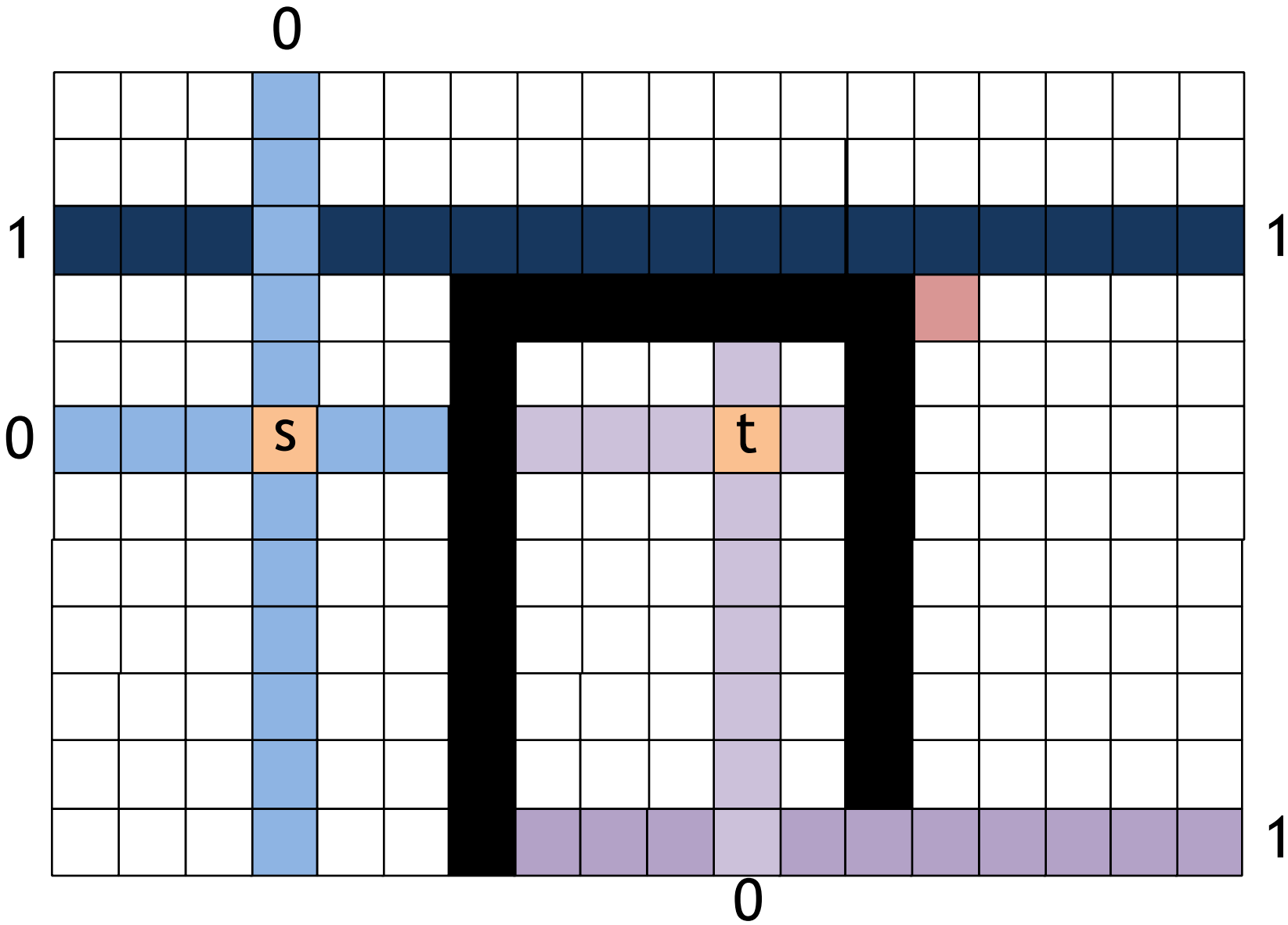
Sink Line Probe (Level 1)



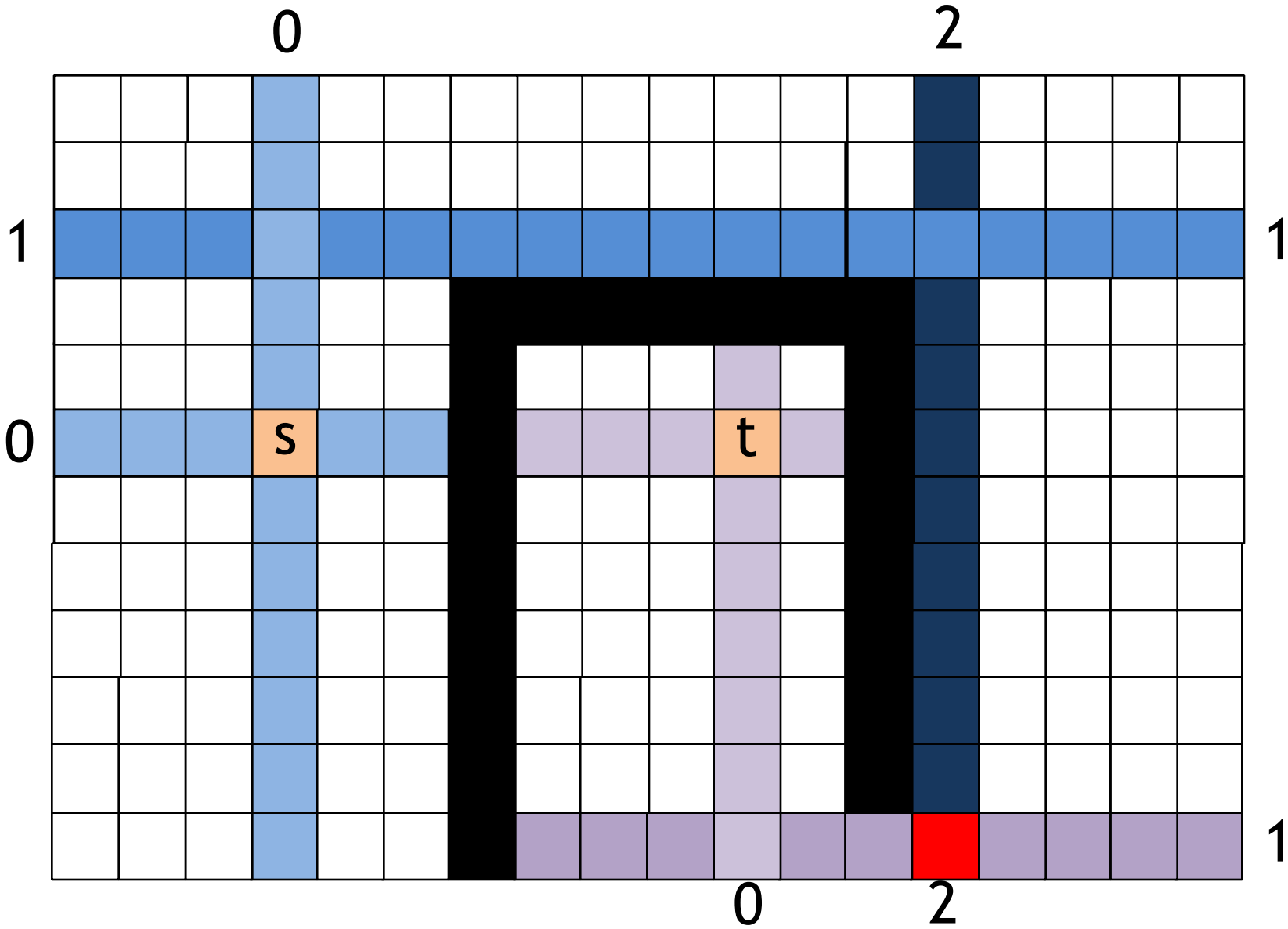
Sink Line Probe (Level 1)



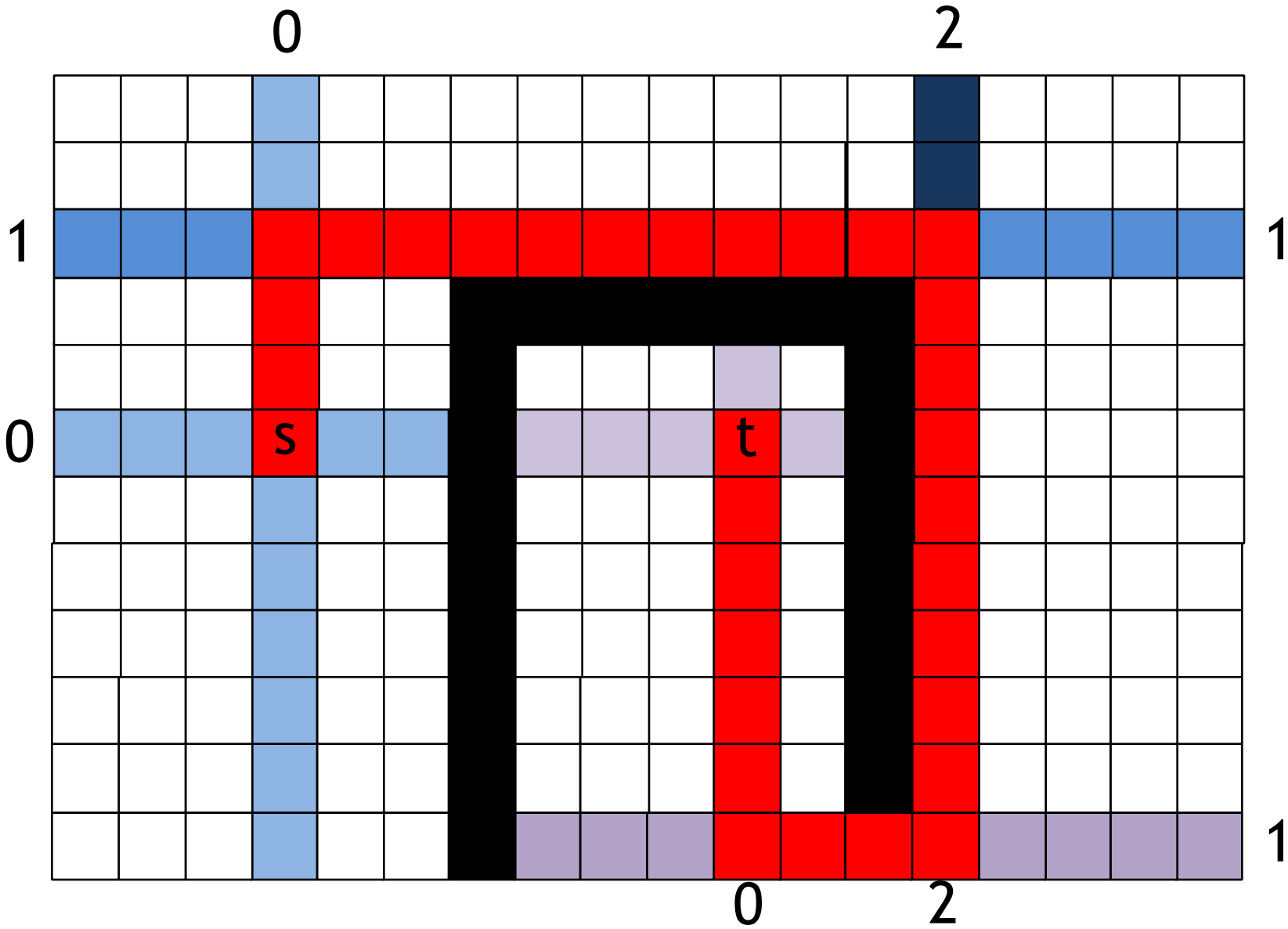
Source Line Probe (Level 2)



Sink Line Probe (Level 1)



After Backtrace



Implementation Issues

- Decompose blocked regions into horizontal/ vertical segments
  - Orientation flag (Horizontal/Vertical)
  - Start/end points for each segment
- Escaping rules are far more detailed than suggested here
- May not always find a legal route if one exists
- O(L), but faster in practice than Mikami-Tochuba