Connection Setup in a Quantum Network

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draft-van-meter-qirg-quantum-connection-setup-01
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Singapore
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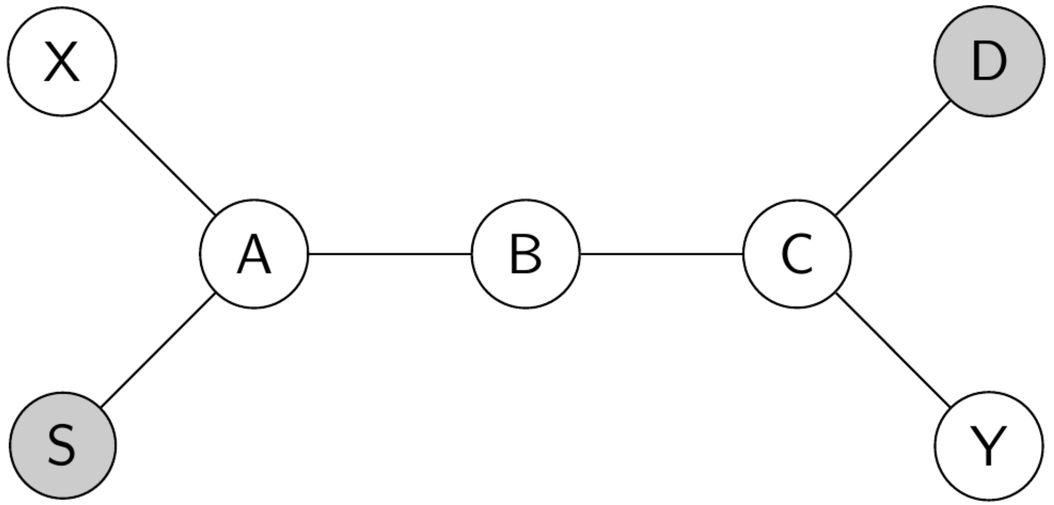
Quantum Connection

Distribution of end-to-end Bell pairs:

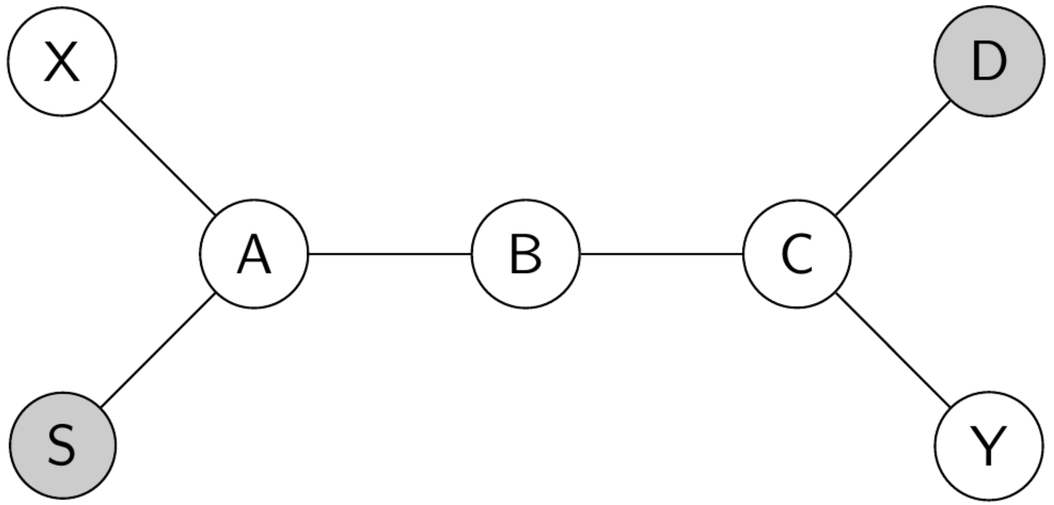
- On request from source node S
- Middle nodes perform entanglement swapping and error management
- See slides from Prague for refresher on our proposed approach



https://datatracker.ietf.org/doc/slides-104-qirg-sessb-connection-setup-in-a-quantum-network/

Stages of the Problem

- Need to select a path (routing)
  https://arxiv.org/1206.5655
- Collect info for planning
  (this draft)
- Plan sequence of operations (RuleSets)
  https://arxiv.org/1904.08605
- Convey sequences to nodes
  (this draft)



Constraints/assumptions

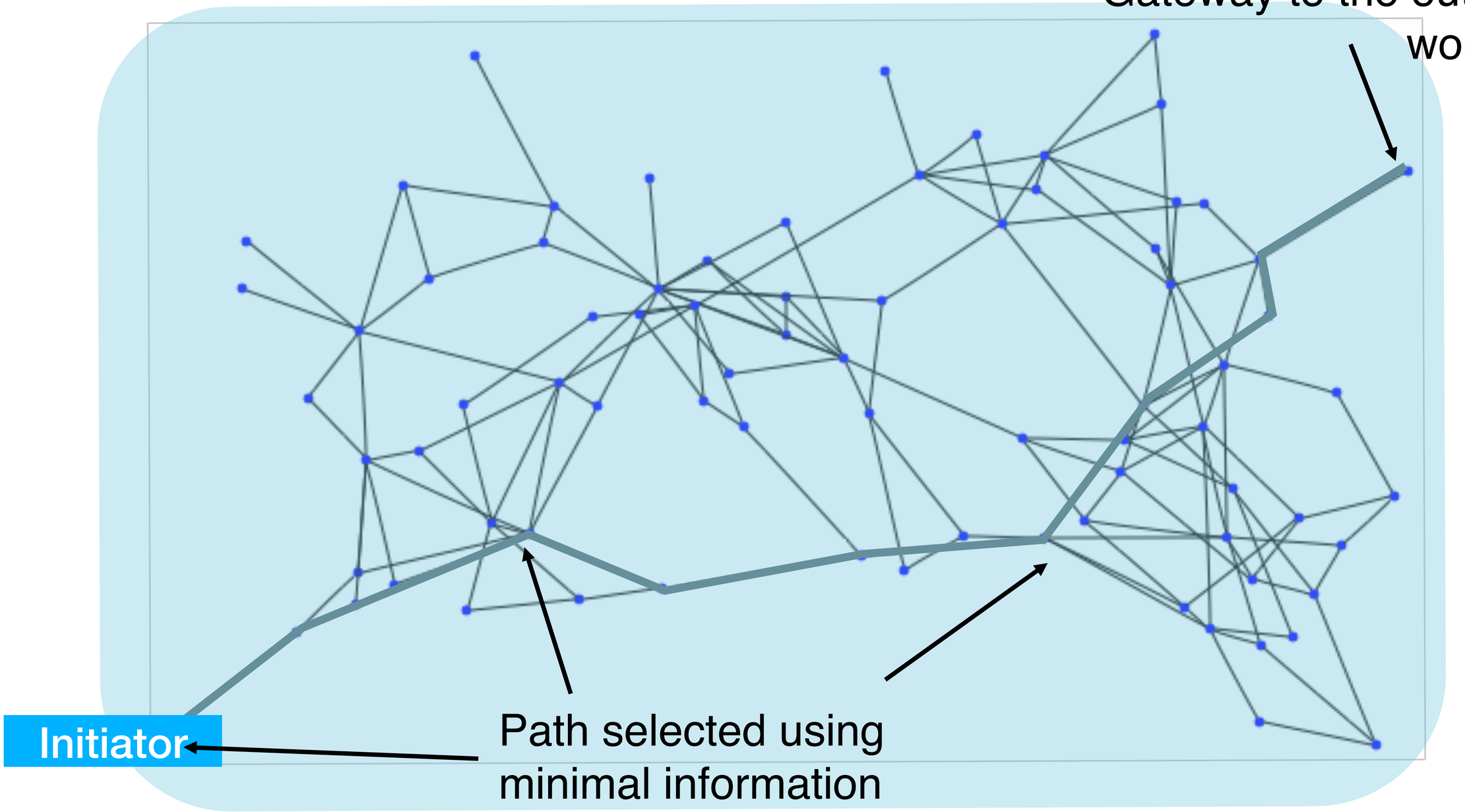
- Links are heterogeneous and not *a priori* known
- Resource management (multiplexing scheme) beyond today's scope, but critically important

Information Each Node Holds

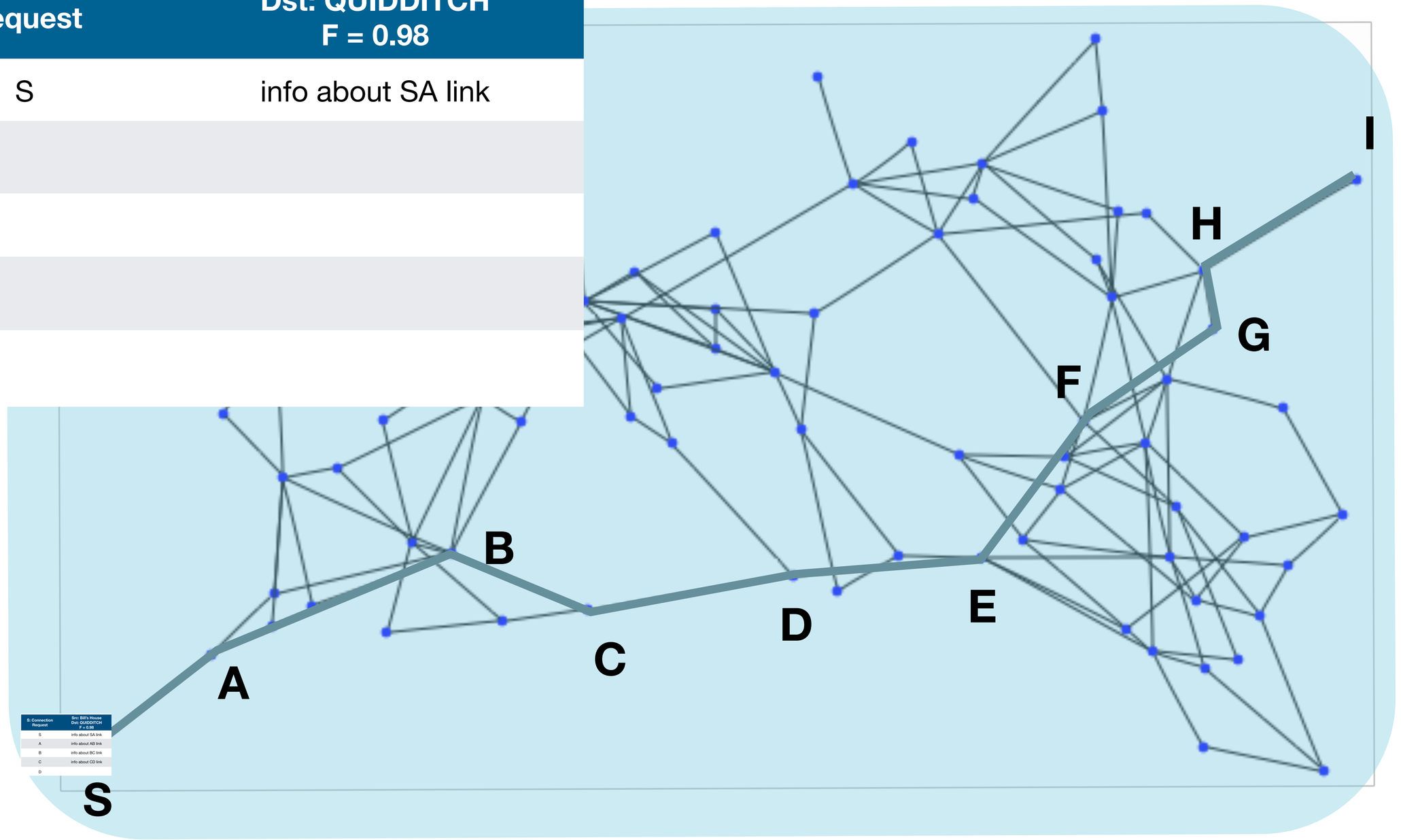
- Its own capabilities
  - amount of memory, memory lifetime
  - gate fidelities
- Link information
  - who neighbors are
  - link entanglement trial rate, success probability, fidelity (or full density matrix)
- Topology of the *local* network, with a routing metric
- Where the gateway to the outside world is

Information Each Node Does *Not* Have

- Full density matrix (noise & decoherence) of the base Bell pairs generated by every node
- Number of qubits in every “QNIC” in the whole network
- Local gate fidelities for other nodes
- Anything at all about the internals of neighboring networks


Gateway to the outer world
Initiator
Path selected using minimal information

S: Connection Request	Src: Bill's House Dst: QUIDDITCH F = 0.98
S	info about SA link



S: Connection Request	Src: Bill's House Dst: QUIDDITCH F = 0.98
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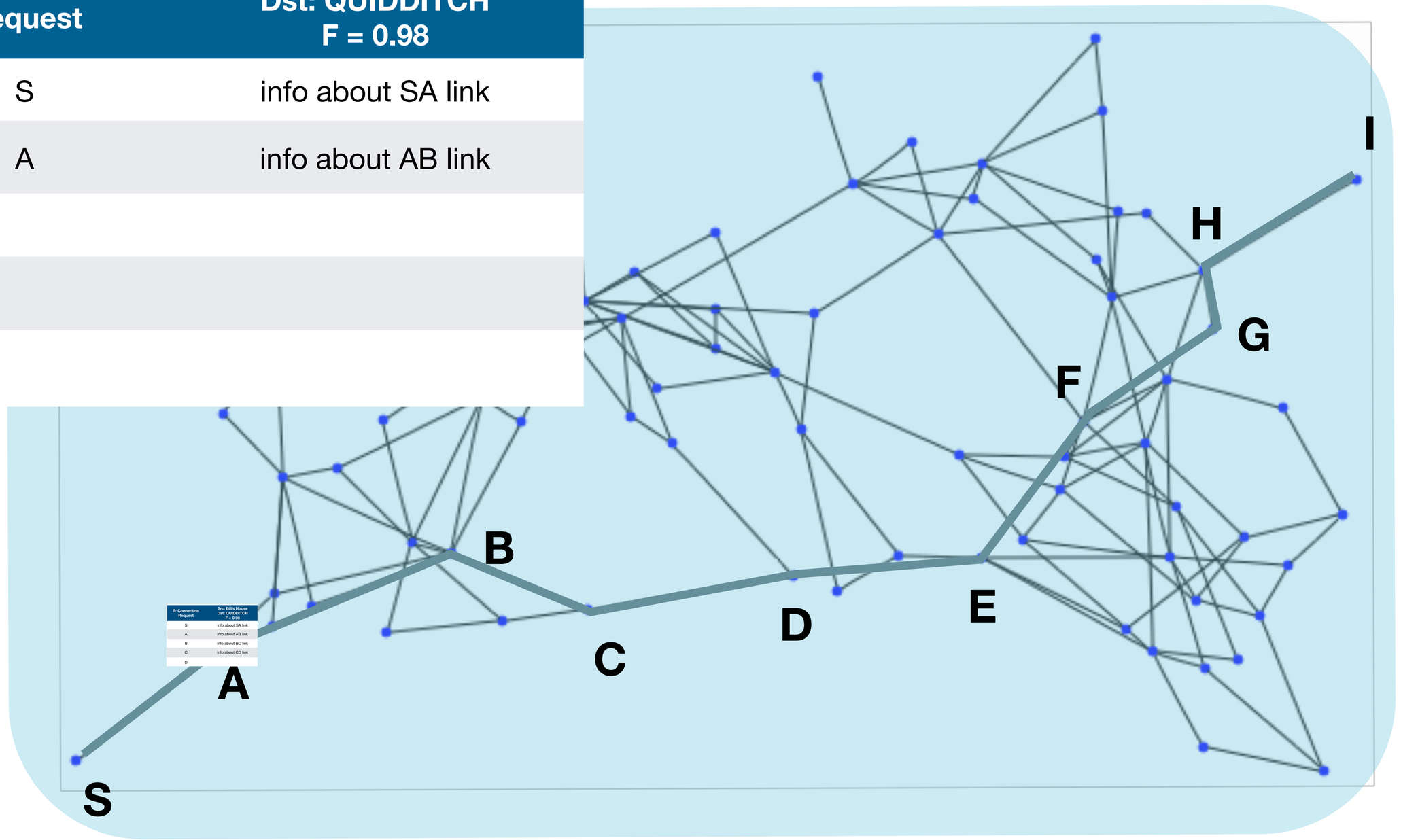
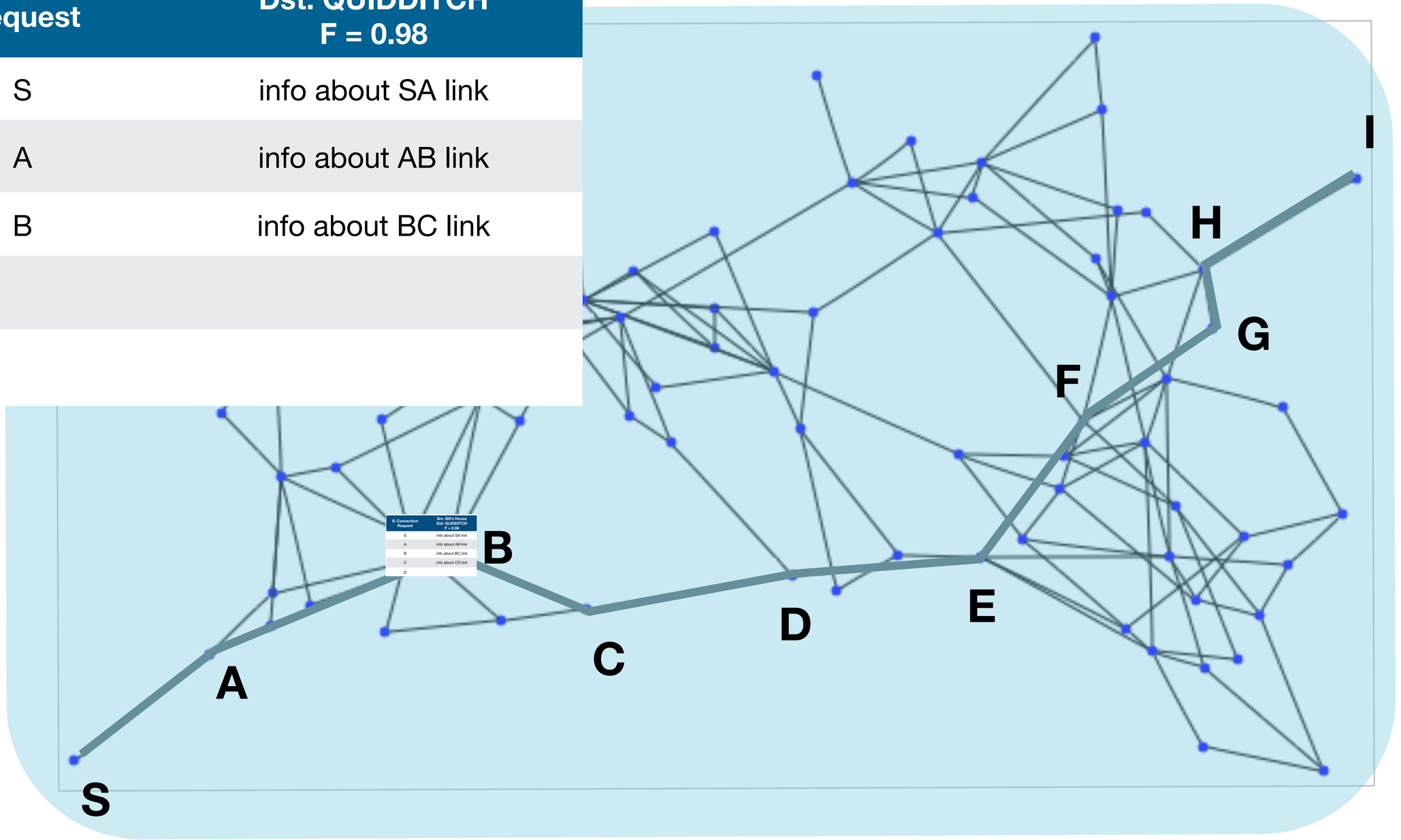
A	info about AB link



S: Connection Request	Src: Bill's House Dst: QUIDDITCH F = 0.98
S	info about SA link
A	info about AB link
B	info about BC link



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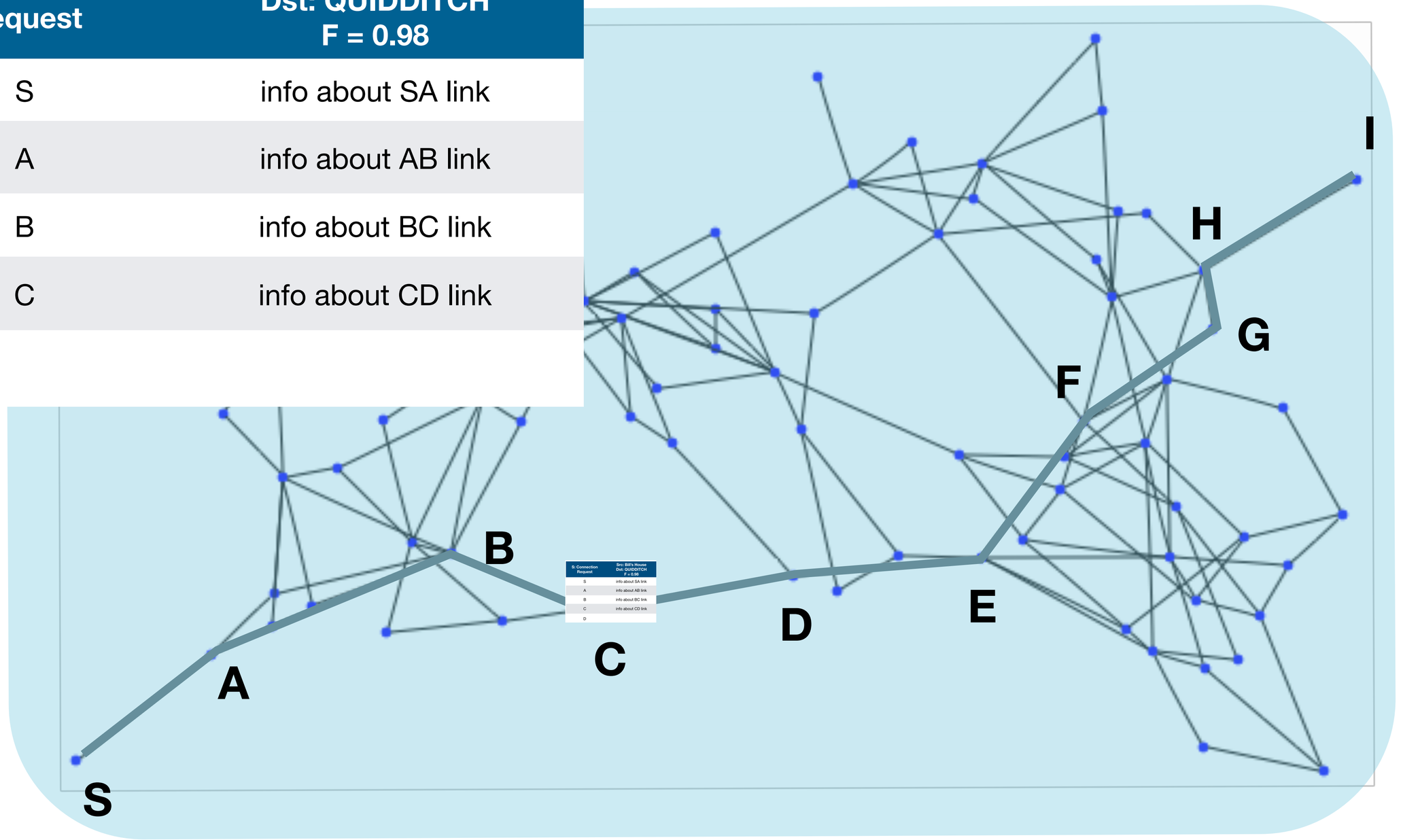
C	info about CD link



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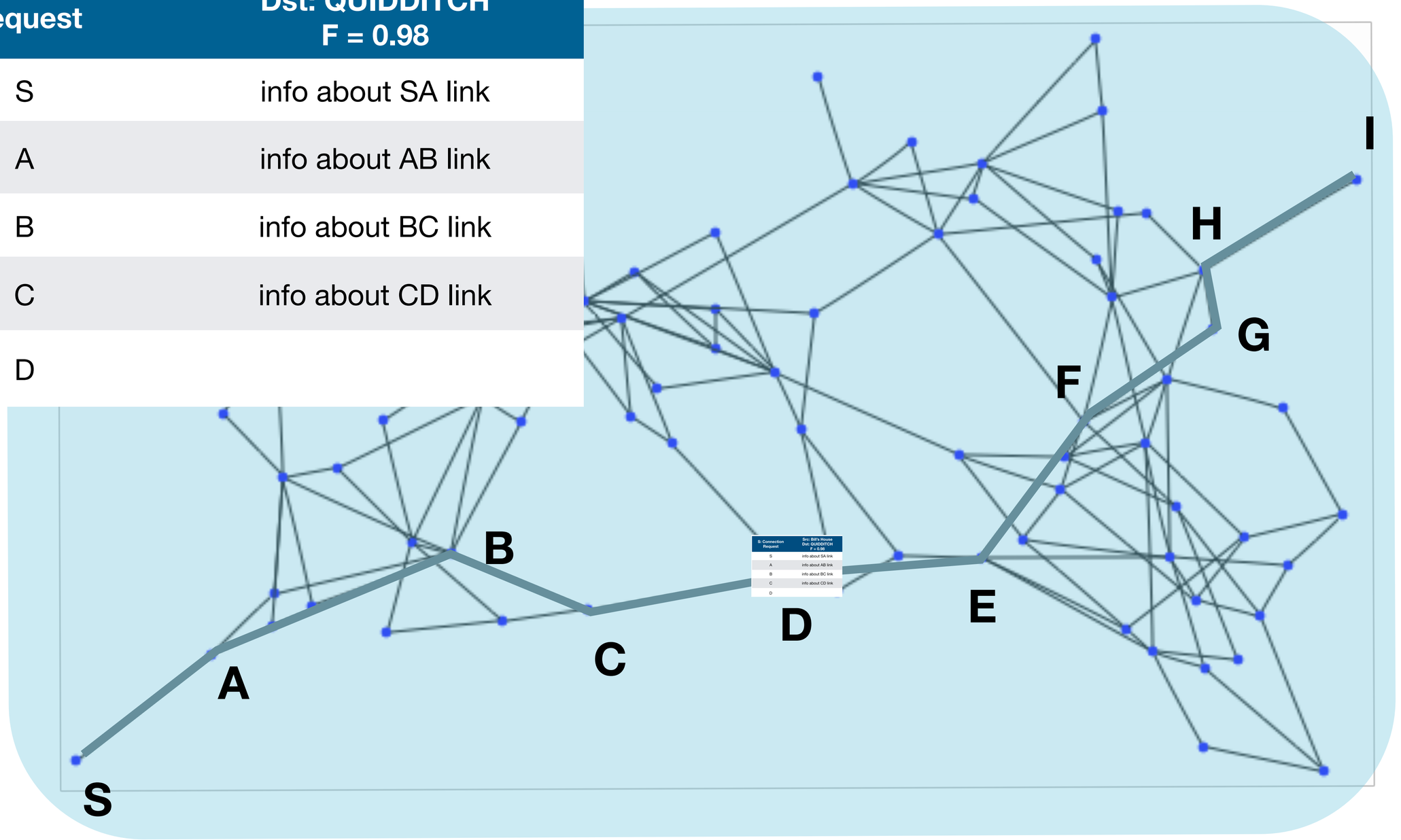
C	info about CD link
D	



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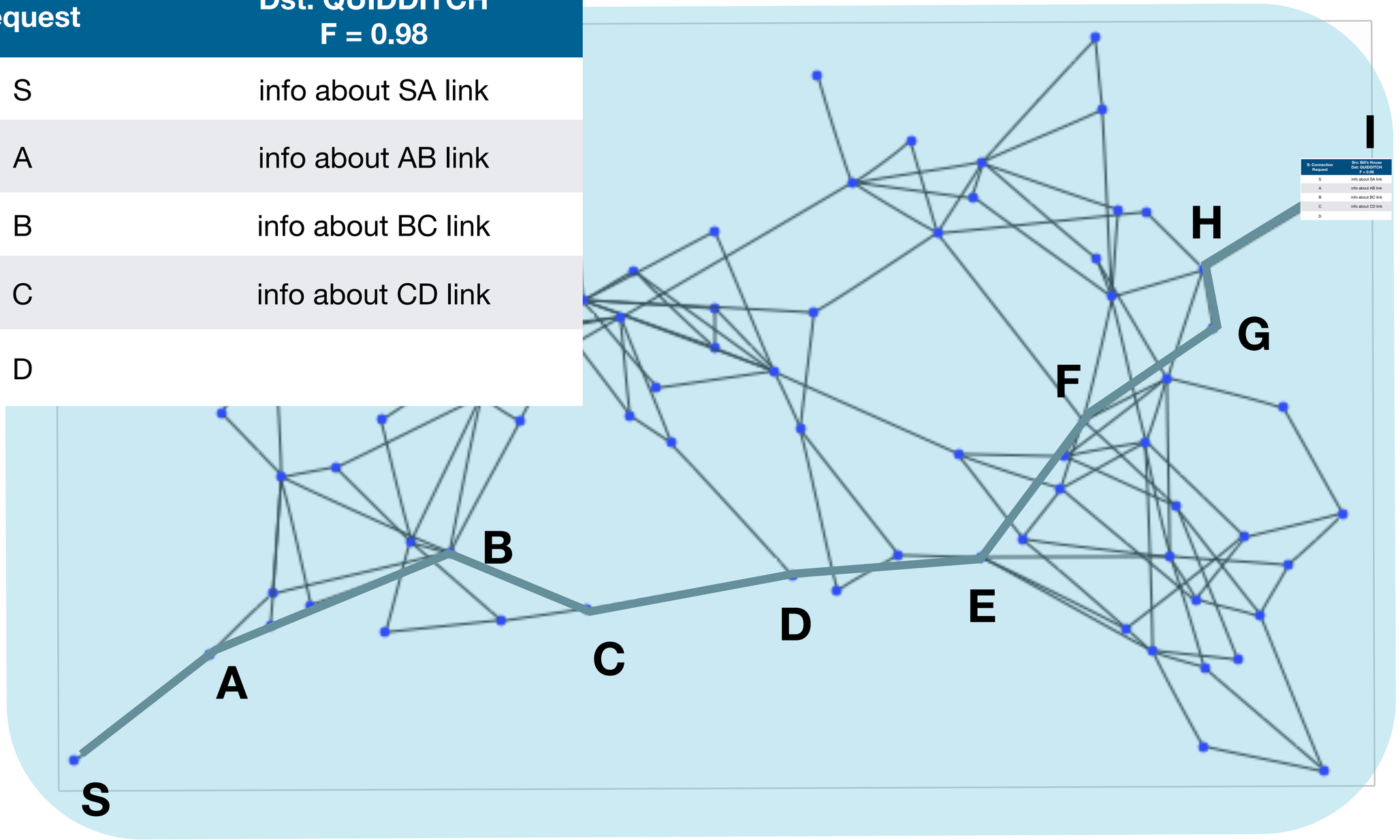

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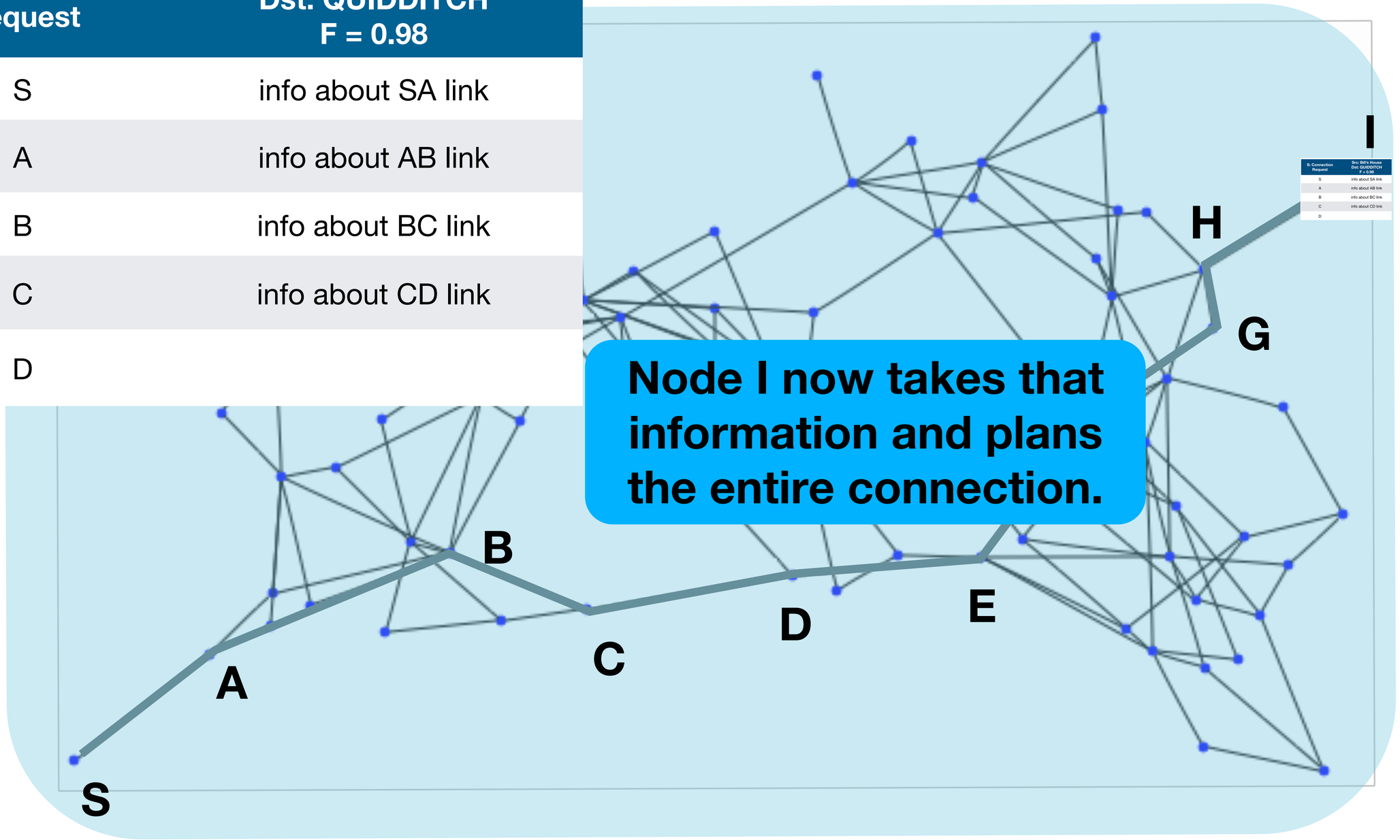

D: Path Setup	Src: Bill's House Dst: QUIDDITCH F = 0.98		
S	conditions to purify conditions to swap		
A	conditions to purify conditions to swap		
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C	purify if BC < 0.98, CD < 0.98	purify if AC < 0.98, CE < 0.98 else swap	
D	purify if CD < 0.98, DE < 0.98 else swap		
E	purify if DE < 0.98, EF < 0.98	purify if CE < 0.98, EG < 0.98	purify if AE < 0.98, EI < 0.98 else swap
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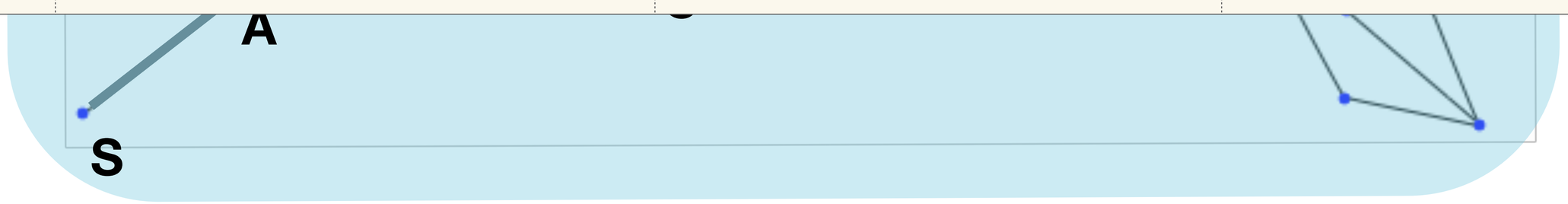

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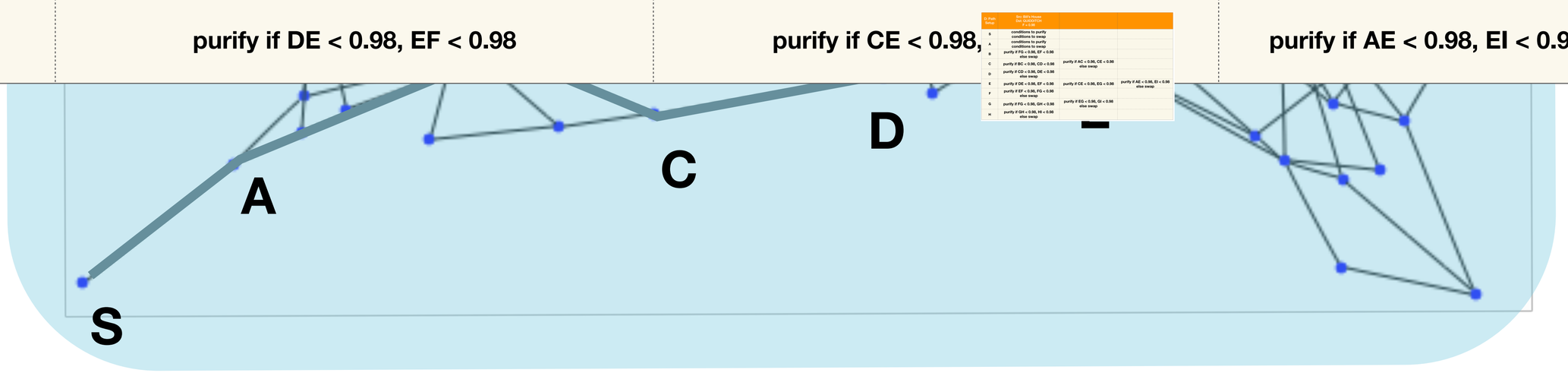

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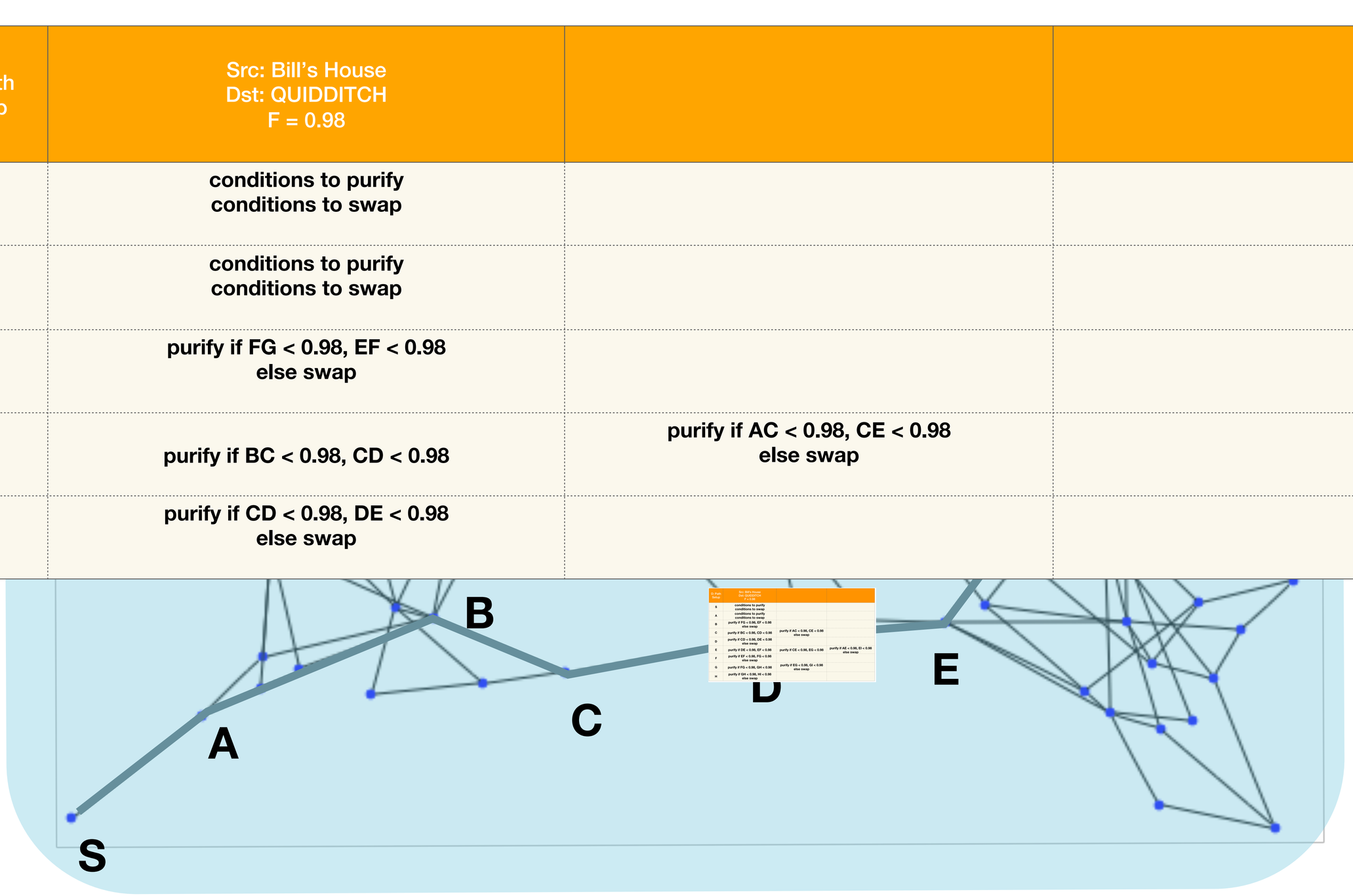

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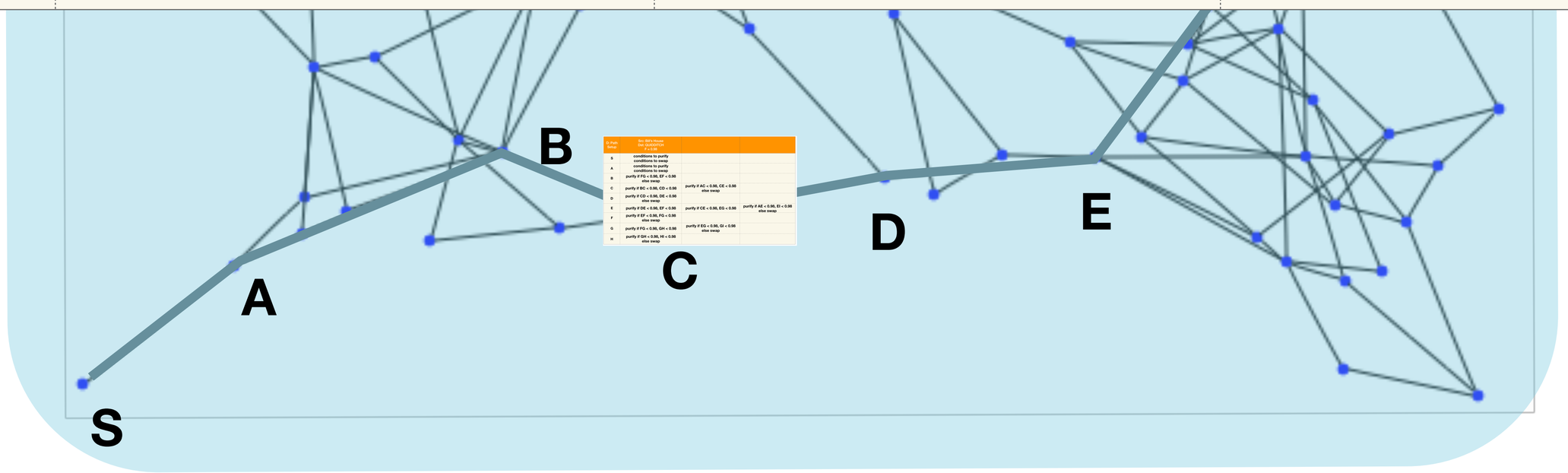

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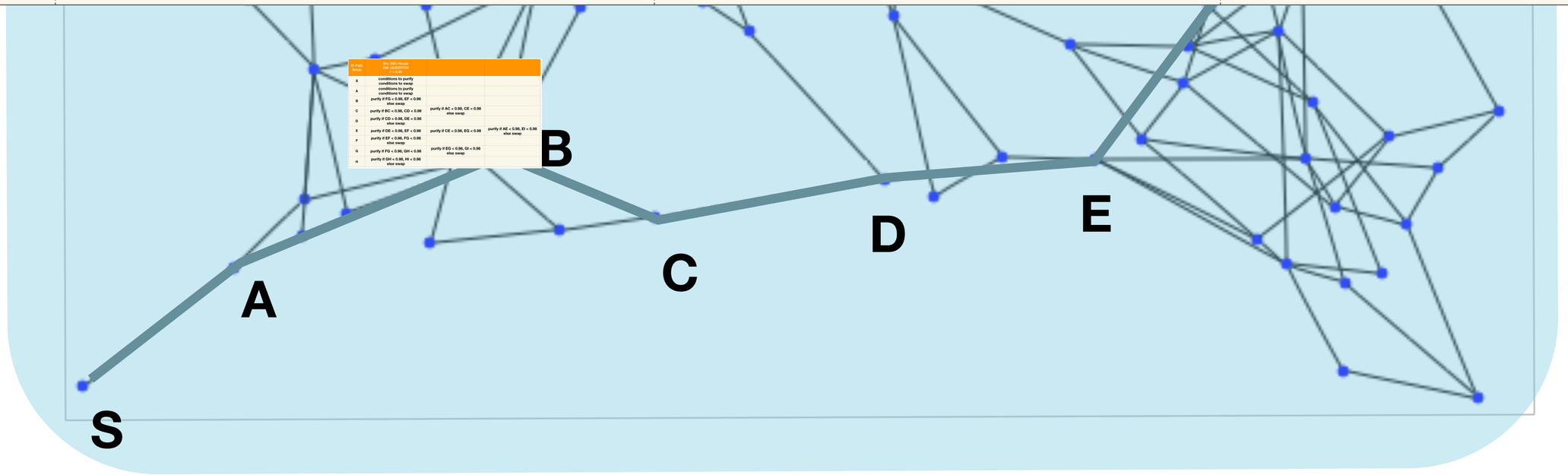

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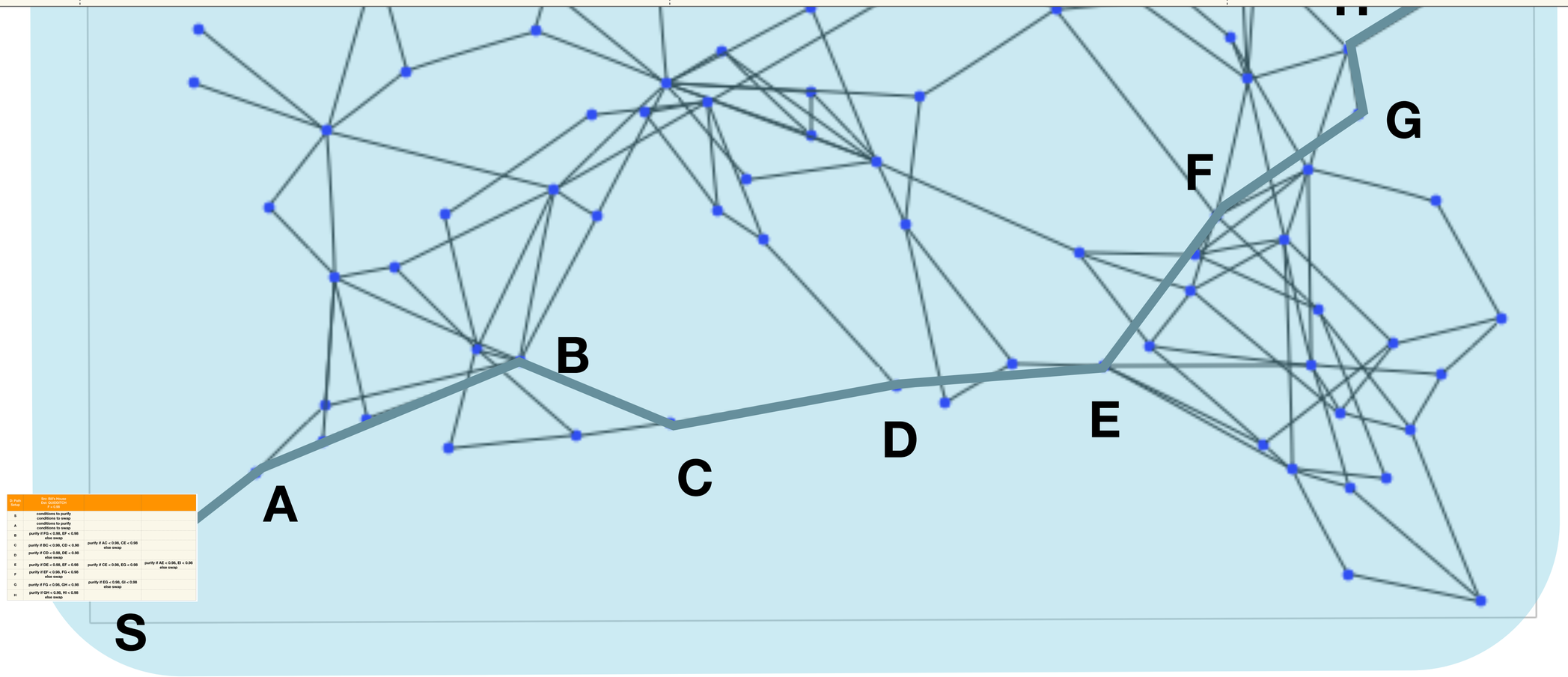

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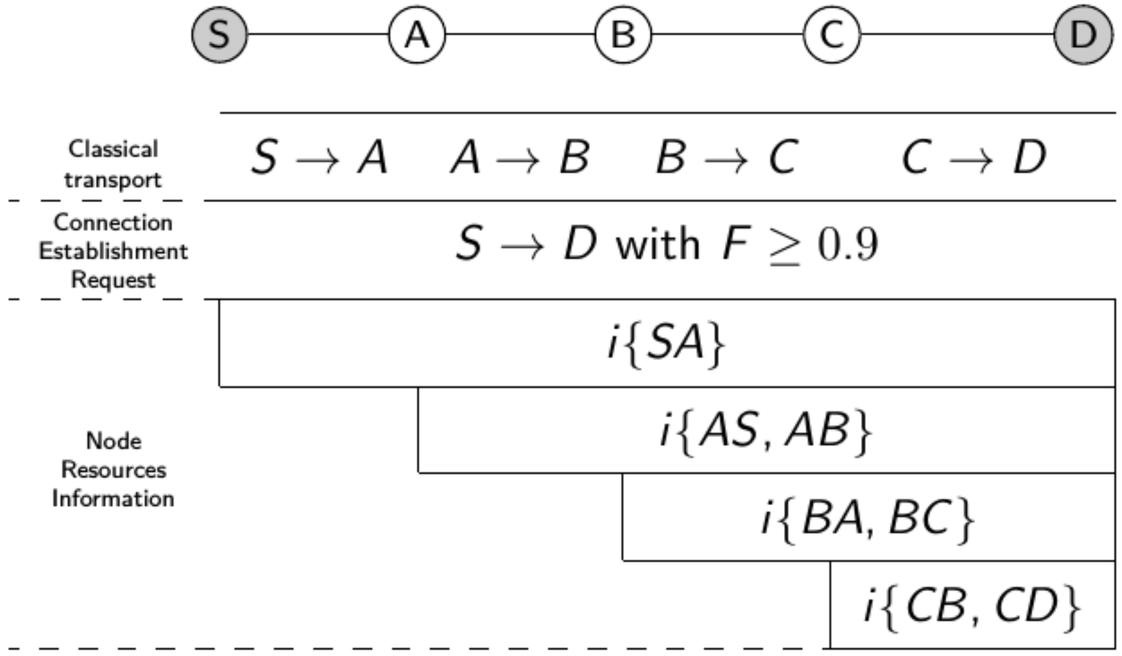
Connection Establishment Request

Used by D to establish rules and Bell pairs distribution.

Nodes provide information about the path:

- Resources
- Quality of the link, etc.

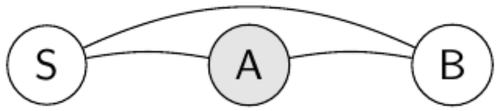


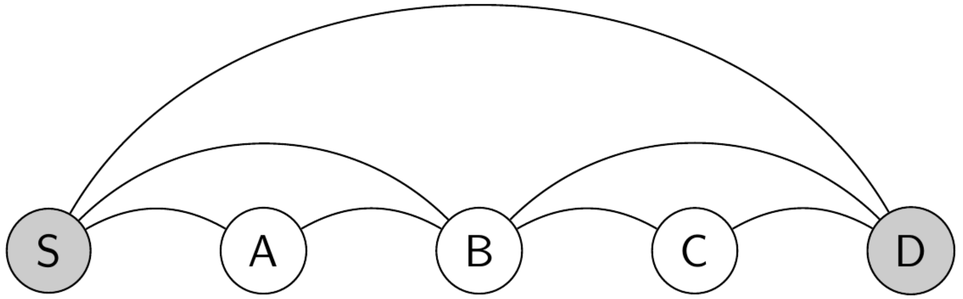
Connection Establishment (Response)

Destination node computes a swapping scheme.

Information provided by the middle nodes is important to create a consistent set of rules.

	Conditions	Actions
Pairs management	$A \sim x$ $F \leq 0.5$	Discard
	$A \sim x$ $A \sim x$ both $F \leq 0.95$	Purify
Swapping	$A \sim B$ $A \sim S$ both $F > 0.95$	Swap

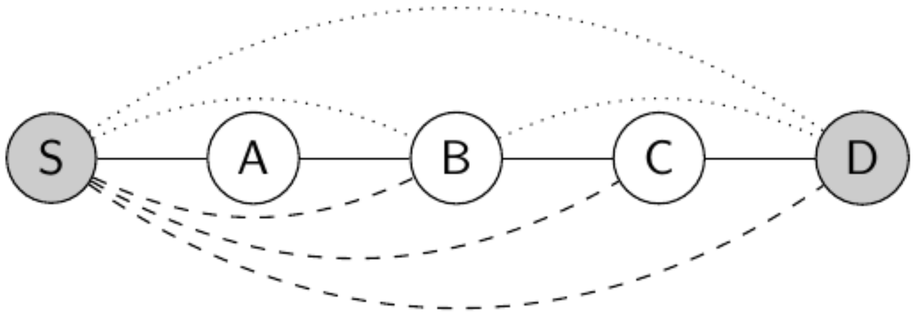




Every node receives a set of rules that will be used to maintain a consistent distributed swapping protocol.

Challenges

- Decomposition choice:
  swapping order hierarchical (top)
  or hop-by-hop (bottom)
- Limiting classical messages
- Consistency of the behaviors of every node
- Class of service



Comments from the ML around Prague

- Q: What about Segment Routing?
- A: Good thought. I'm not familiar w/ the current SR, but waypoint routing + circuit/reservation setup is what I have in mind.

  Moreover, intended to be recursive, treating each network as a node in a larger graph (more than just two-layer IGP/EGP).

  Status: Not addressed yet; who knows enough about SR to help here?

Diffs -00 to -01

- Minor diffs only so far
- Improved definition of End Node should coordinate w/ arch draft
- Improved definition of Repeater should coordinate w/ arch draft
- Improved discussion of non-data-teleportation uses of entanglement
- Added a little discussion of multiplexing/resource management, but nothing prescriptive yet.

Open Issues, ML Fall and Summer

- Multi-partite entanglement (Frédéric, Patrick, Wojciech, Nov. 12~)
  - Answer: Prefer to defer this to future work due to complexity
- Connection teardown! (Patrick, Apr. 30~)
- Move from « condition & action » to « match & action » (Wojciech, Sep. 7)
  - A: okay by me, but is it useful?
- Separate RuleSet definition from RS distribution (Wojciech, Sep. 7)
  - A: That is indeed the goal, though I-D text talks about the kinds of things to be included
- Single-domain or inter-network? (Wojciech, Sep. 7)
  - A: This draft is currently single-domain, but plan is recursive network architecture https://arxiv.org/abs/1105.1238
- Coordinate w/ link layer doc

Plans -01 to -02

- SR?
- Resource management/allocation – defer? Too big an issue
- Coordinate w/ terminology from arch draft