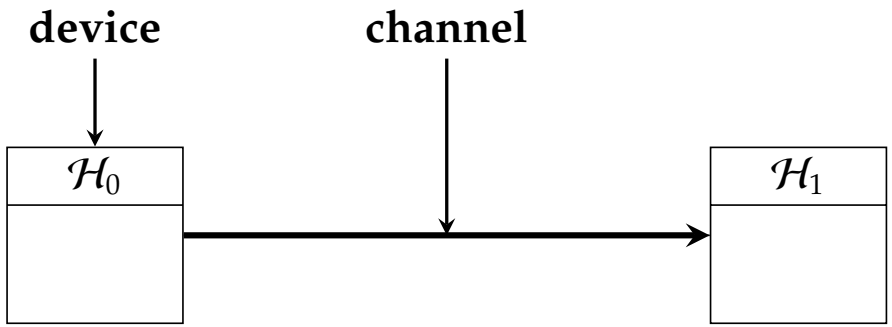
- We can *already* form a simple **point-to-point** communication channel



using TIA-232-F.

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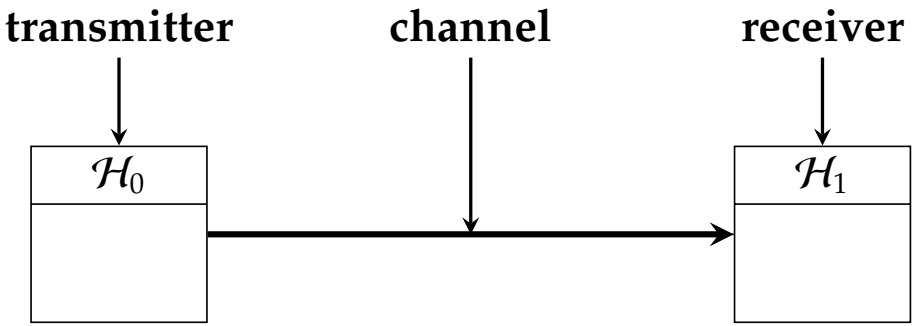

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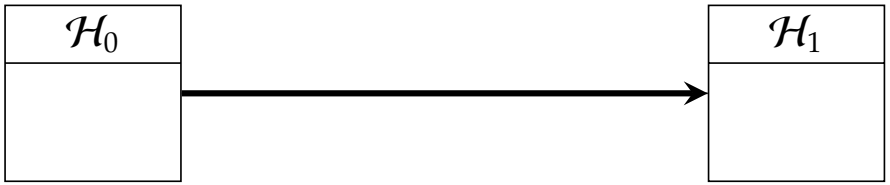
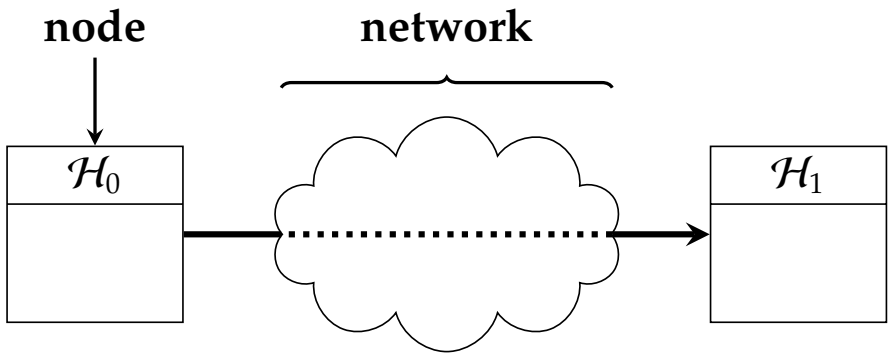


using TIA-232-F, st.

- Good:
  - modular wrt. communication medium and protocol,
  - uses standardised components,
  - ...
- Bad:
  - well defined, but quite limited functionality,
  - the organisation of components is fixed,
  - there are limits wrt. physical locality,
  - ...

- We can *already* form a simple **point-to-point** communication channel



using TIA-232-F.

- Challenge: expand our remit to use of a **computer network** ...

- ... *how*?

- ... *how*?
  1. Requirements: what do we expect from a network?
     - supports a high degree of connectivity,
     - allows inter-operation between heterogeneous components,
     - uses appropriate level of abstraction to provide useful functionality,
     - satisfies any relevant quality metrics (e.g., efficiency, reliability),
     - can be (dynamically) scaled wrt. components and usage.

- ... *how*?

2. Architecture: how should we approach the design of a network?
   - (physical or logical) **topology**, i.e., the structure of components in the network, plus
   - control i.e., how do we use those components to communicate, and
   - standardisation, i.e., how do we ensure components which communicate can **inter-operate**.

Problem #1: topology (1)

- Idea #1: *fully*-connected, st. $\mathcal{H}_i$ is connected to $\mathcal{H}_j$ for $j \in S = \{0, 1, \ldots n-1\} \setminus \{i\}$.

- Note that access to a given channel may be
  1. **dedicated**, or
  2. **shared**, implying a need to control access but also the posibility to **broadcast** to *multiple* receiving nodes.

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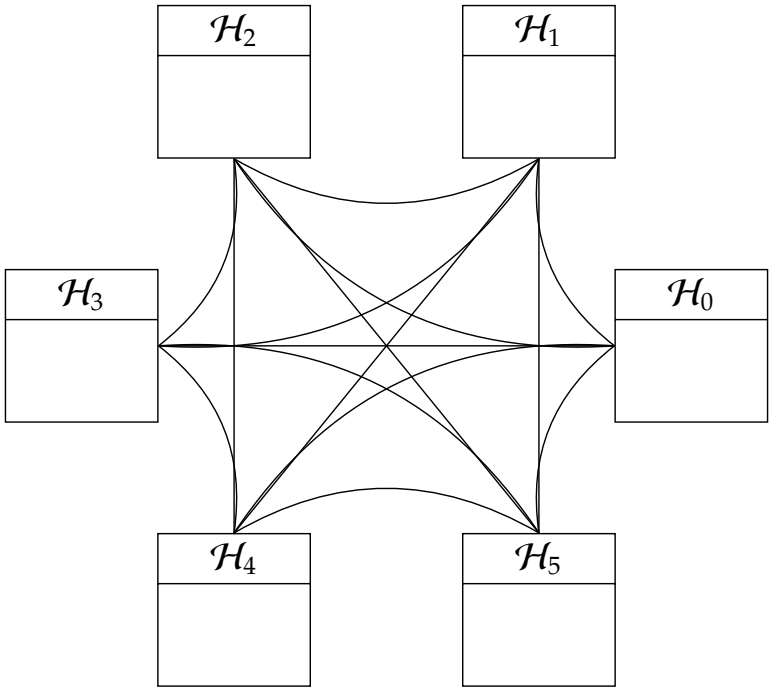
- Example: a **mesh topology**, i.e.,



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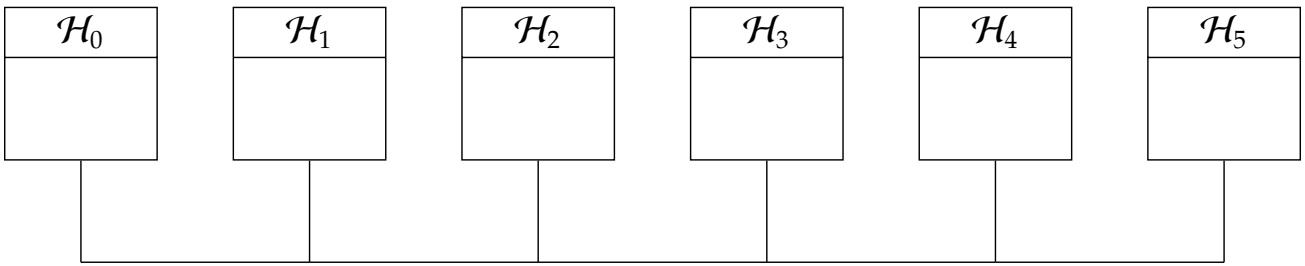
- Example: a **bus topology**, i.e.,



- Note that access to a given channel may be
  1. **dedicated**, or
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Problem #1: topology (2)

- Idea #2: *partially*-connected, st. $\mathcal{H}_i$ is connected to $\mathcal{H}_j$ for $j \in S \subset \{0, 1, \ldots n-1\} \setminus \{i\}$.

- Note that connectivity may now be either
  1. **direct**, or
  2. **indirect**, implying a need for intermediate **hops**, e.g., as realised via **store-and-forward** by (intermediate) switching nodes.

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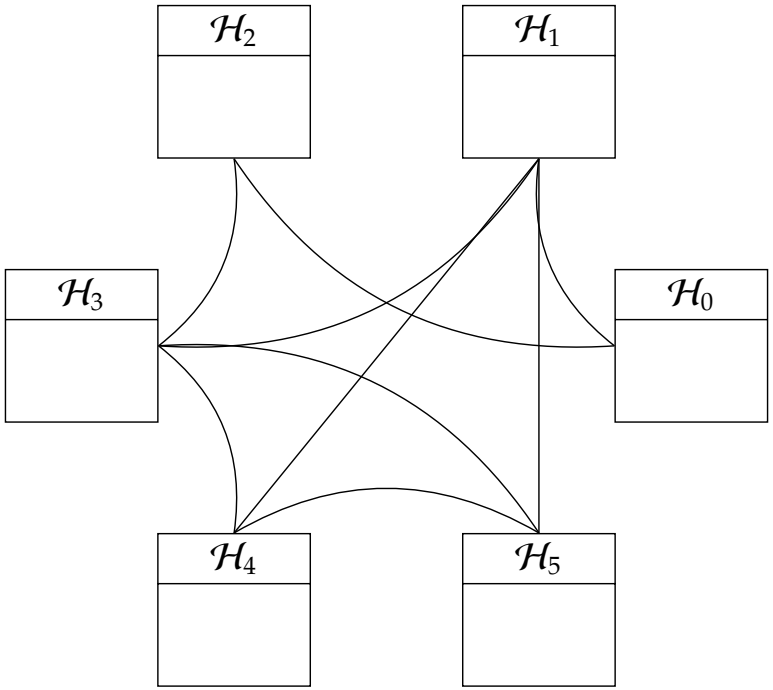

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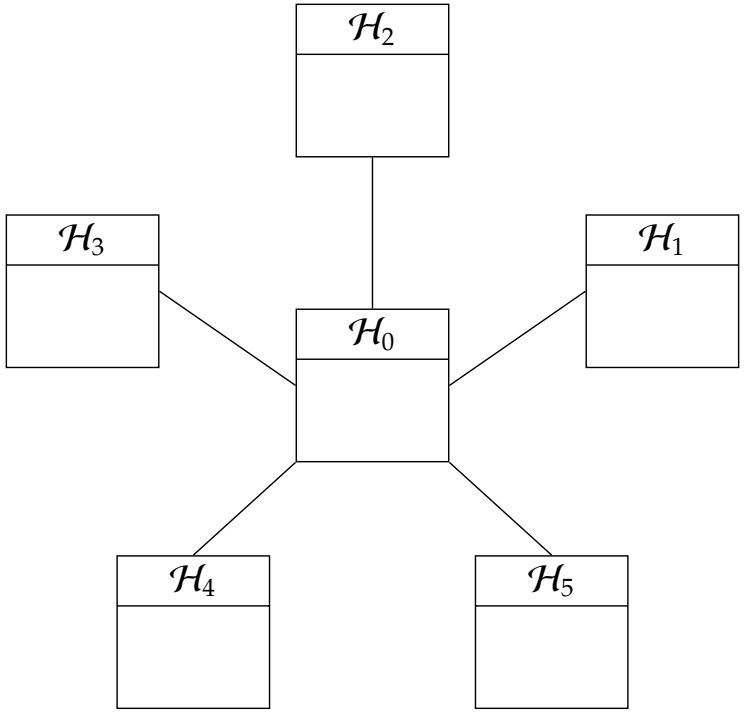
- Example: a **star topology**, i.e.,



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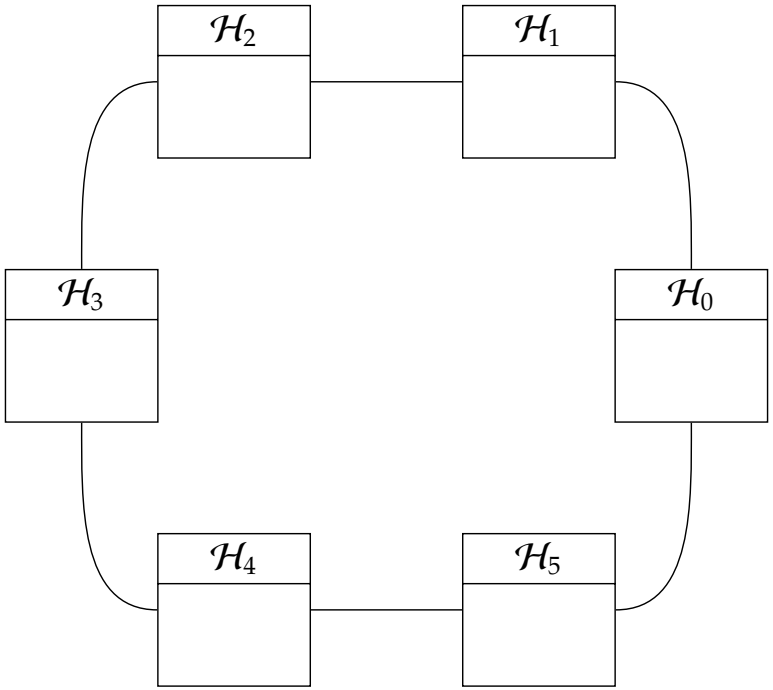

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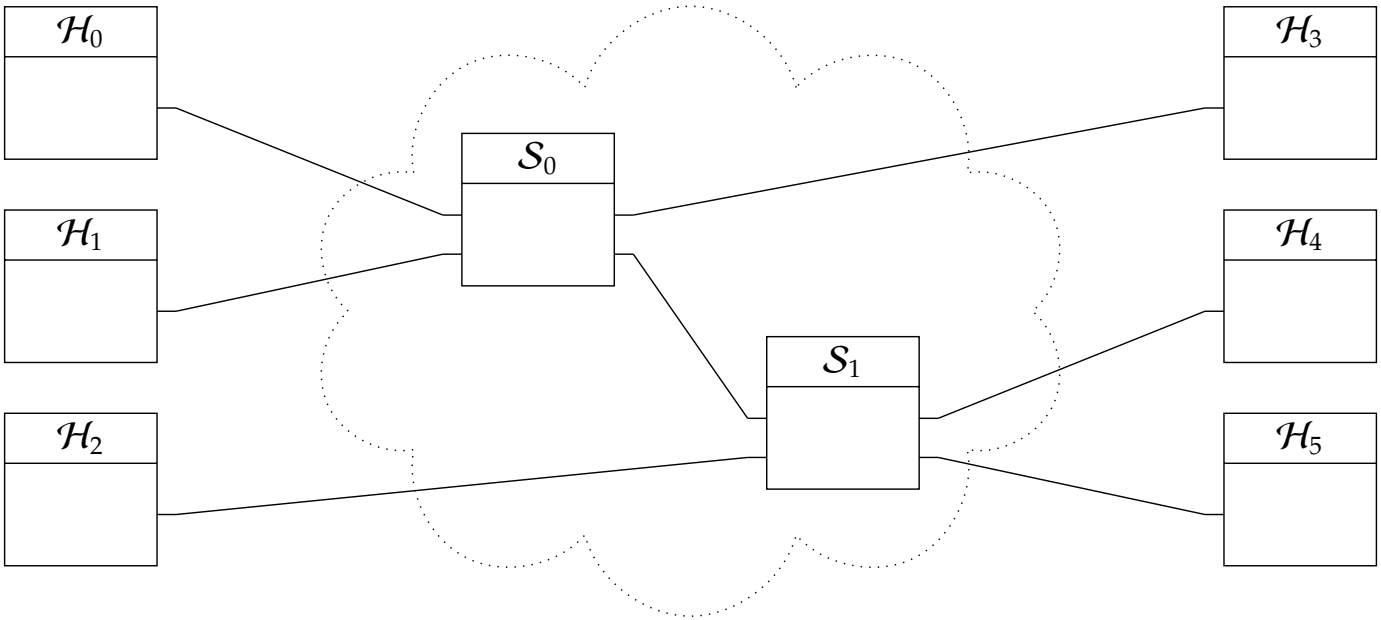
Problem #1: topology (3)

- We can *generalise* partially connected network topologies



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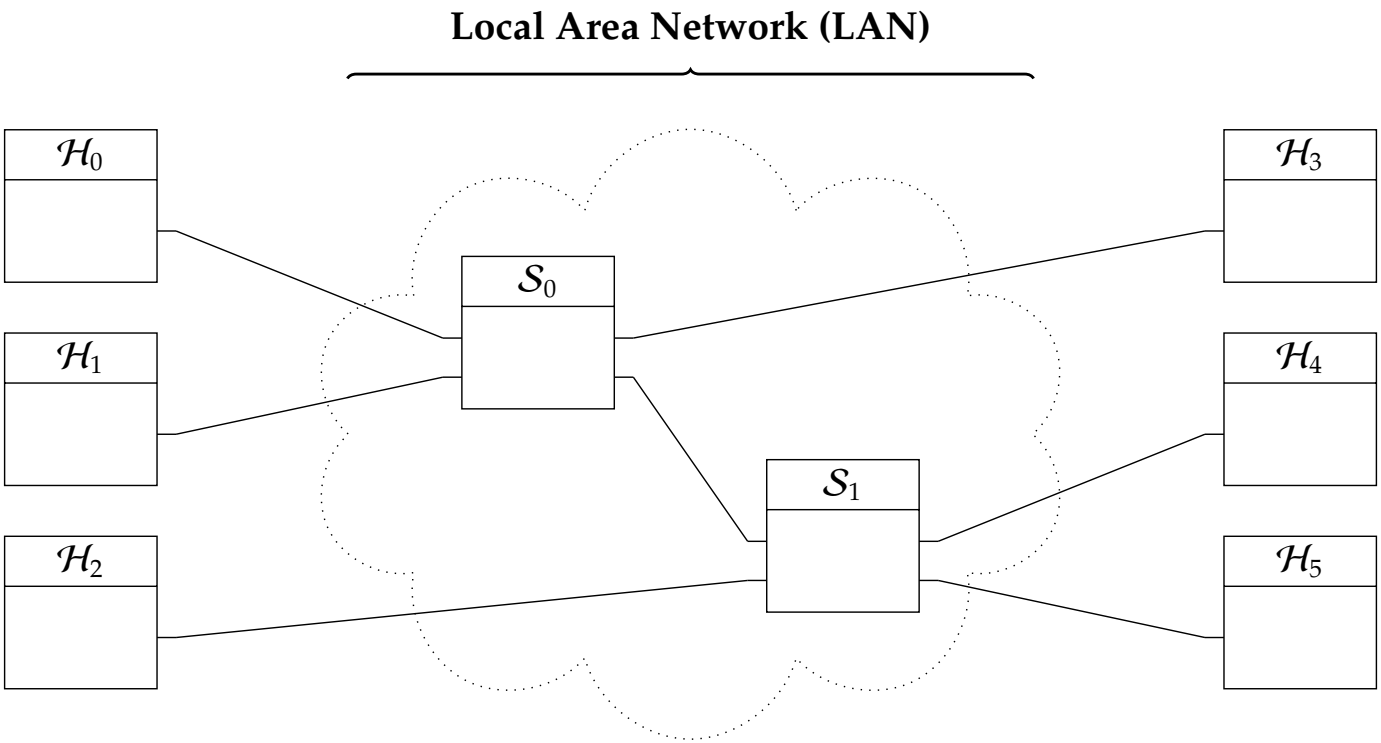

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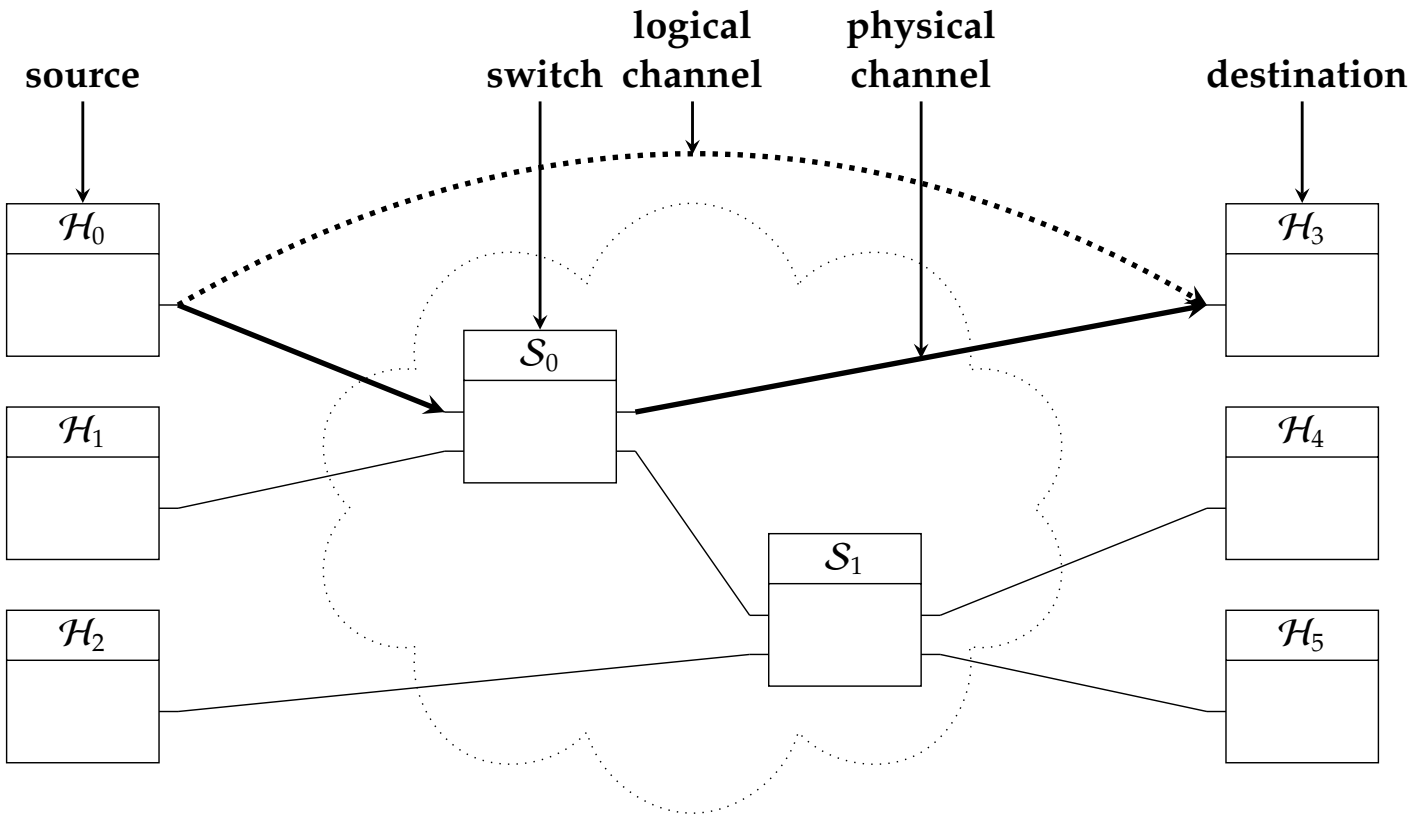

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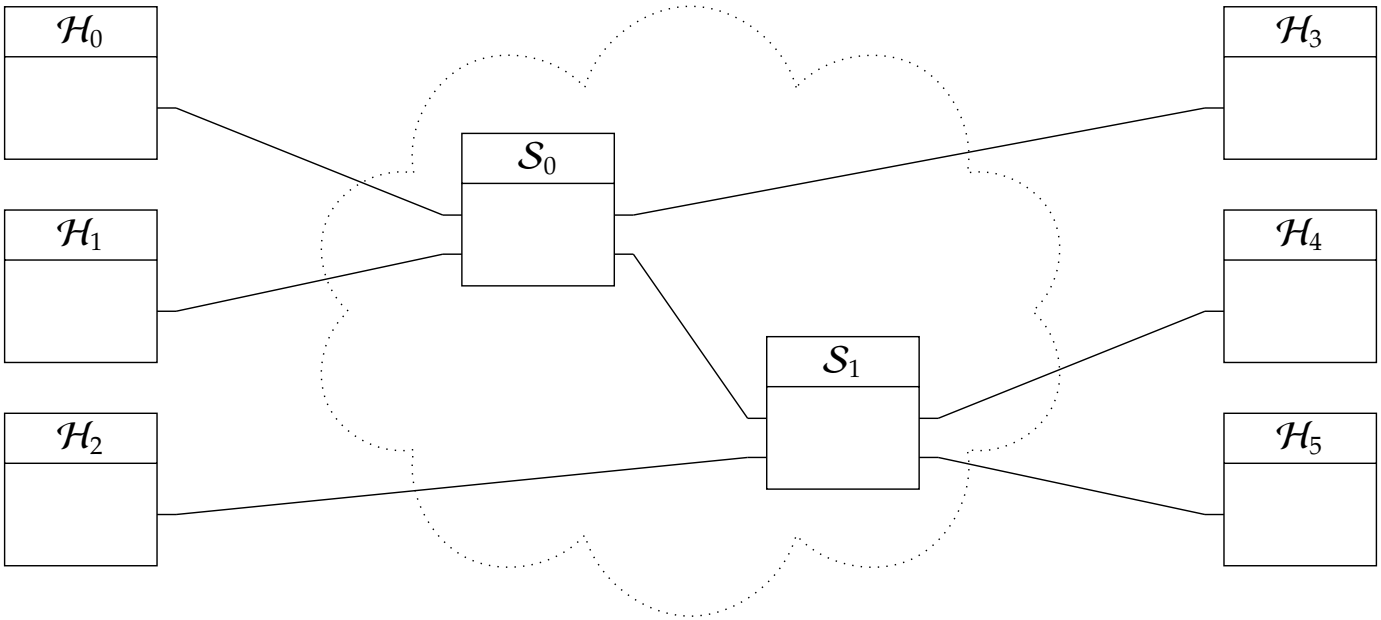

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- **circuit switching** and
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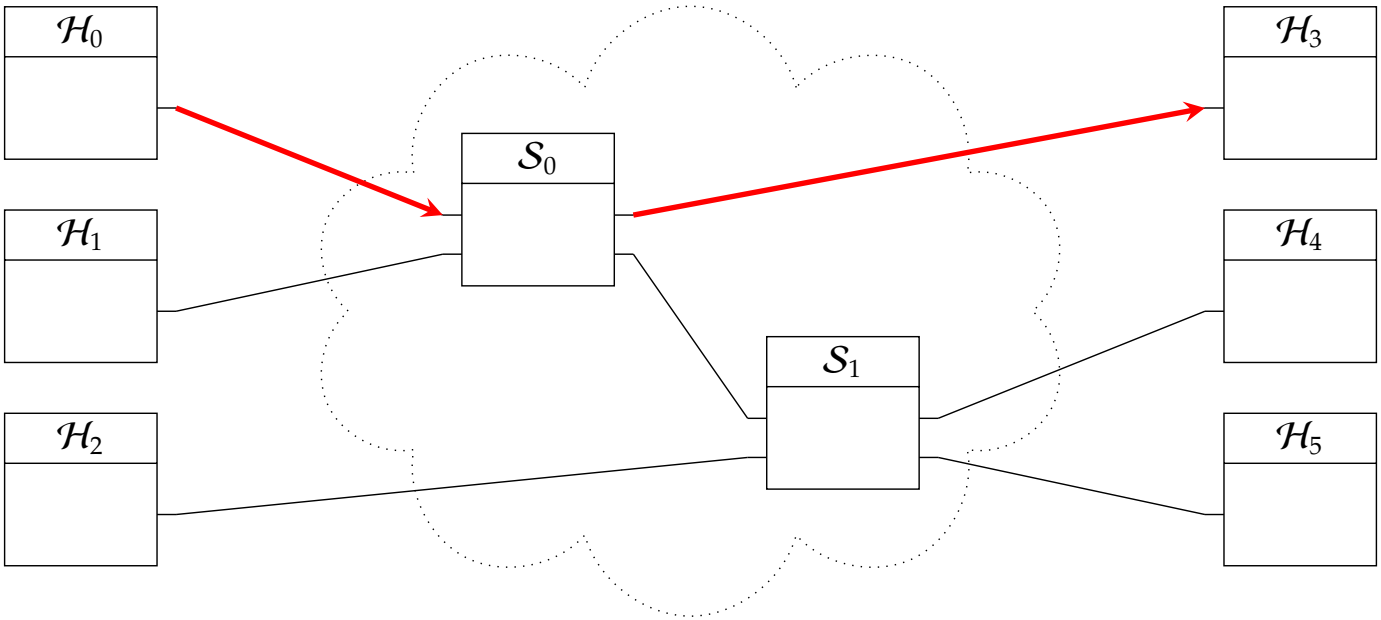

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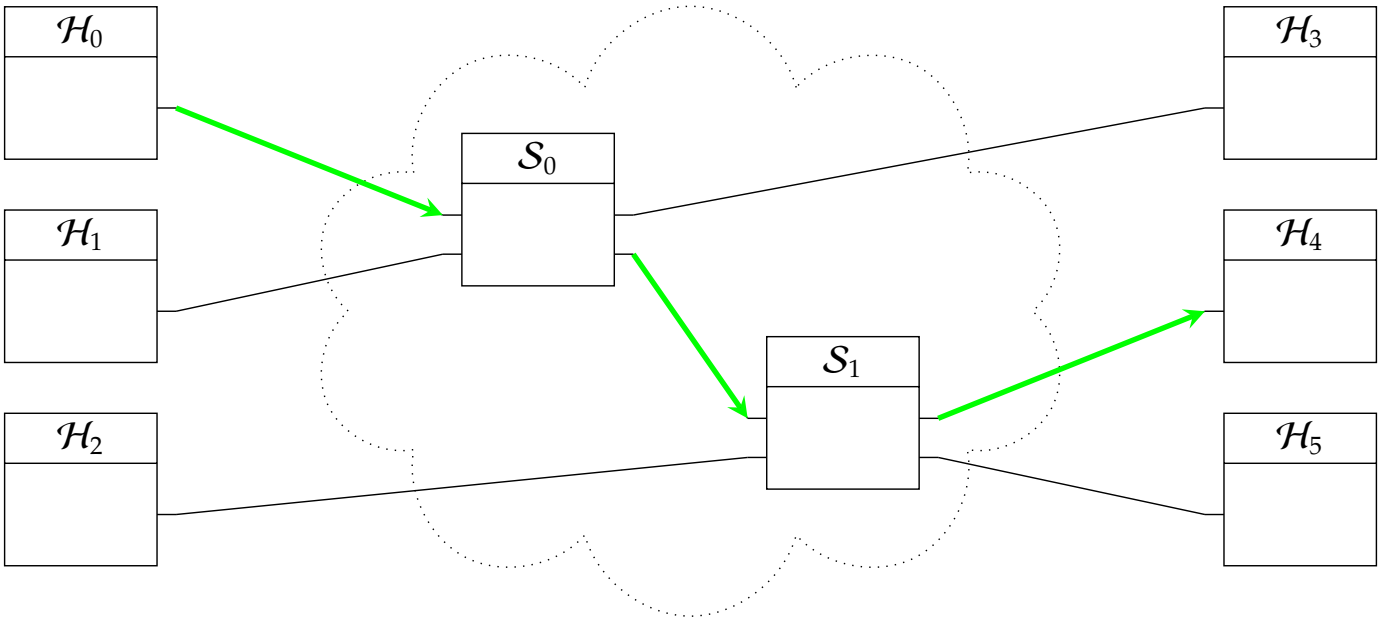

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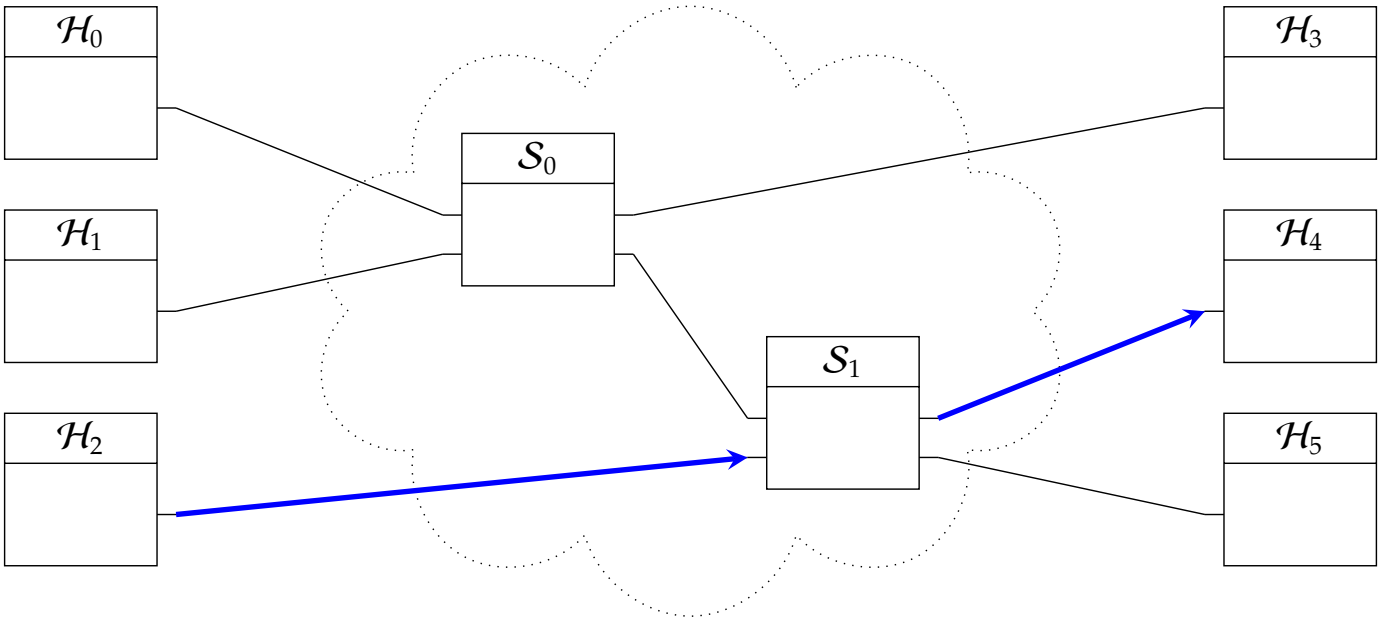

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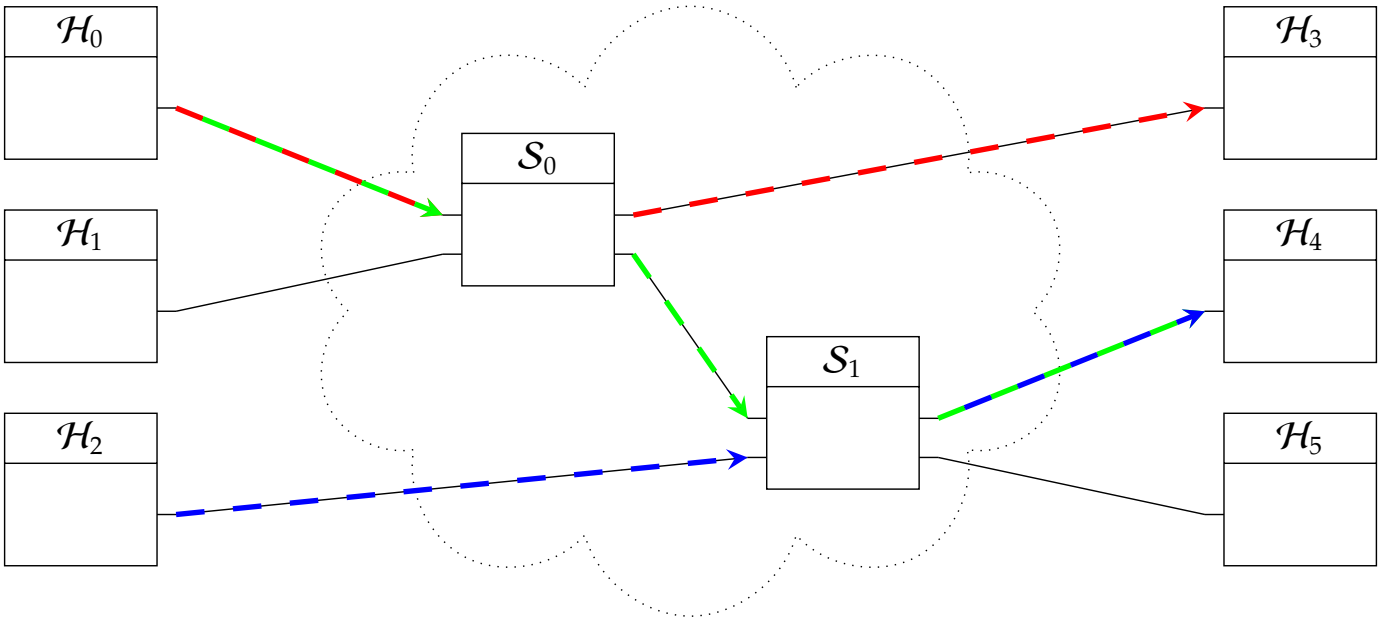

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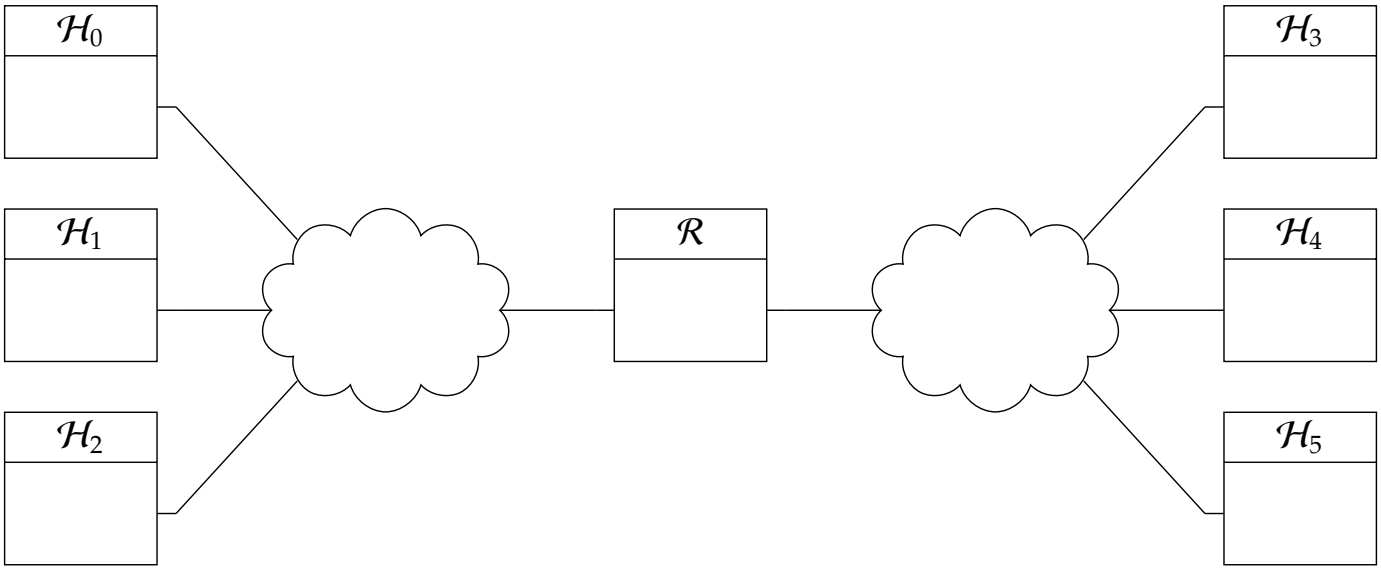

then, finally, noting

- a network provides connectivity between nodes, while
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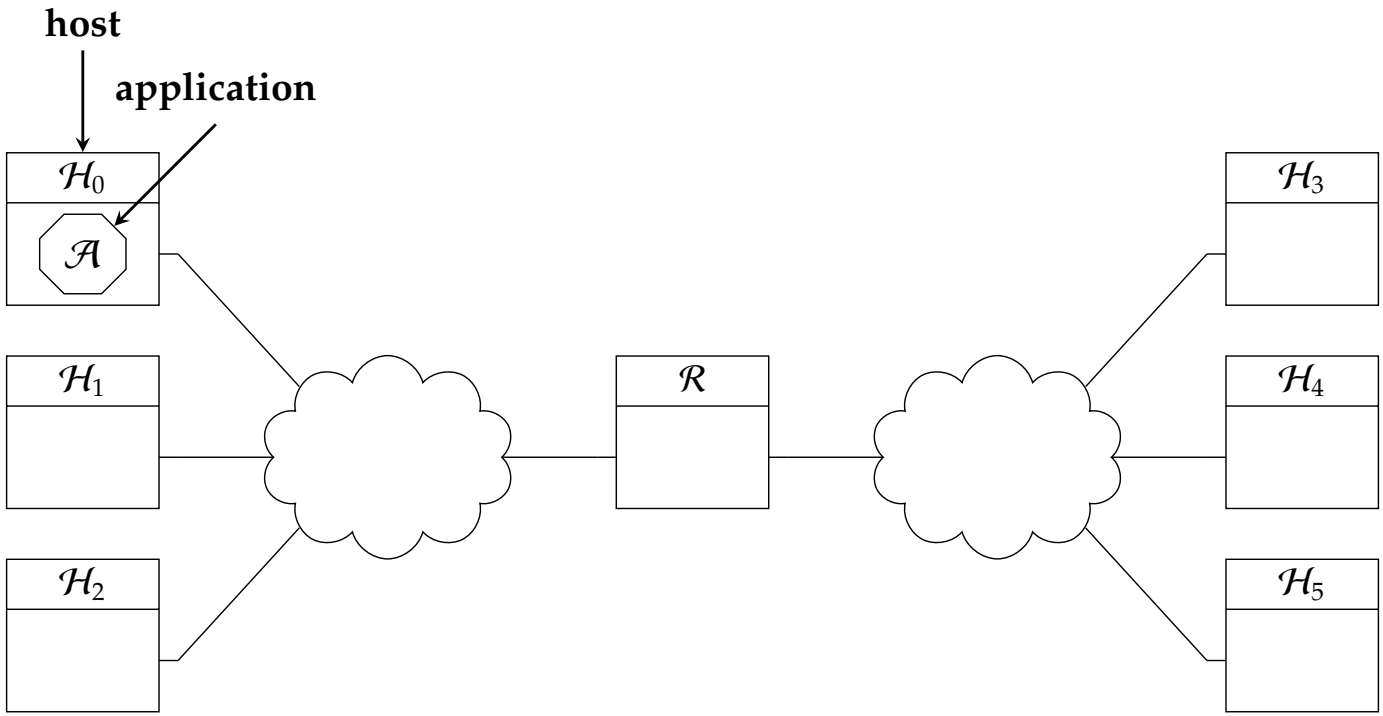

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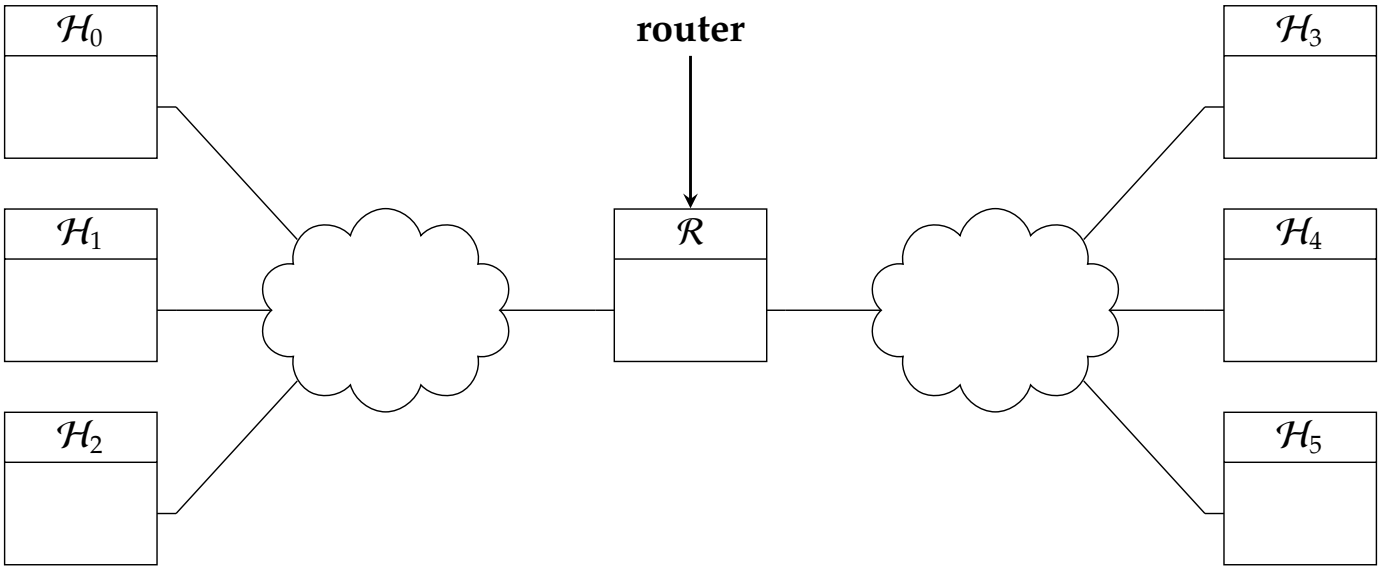

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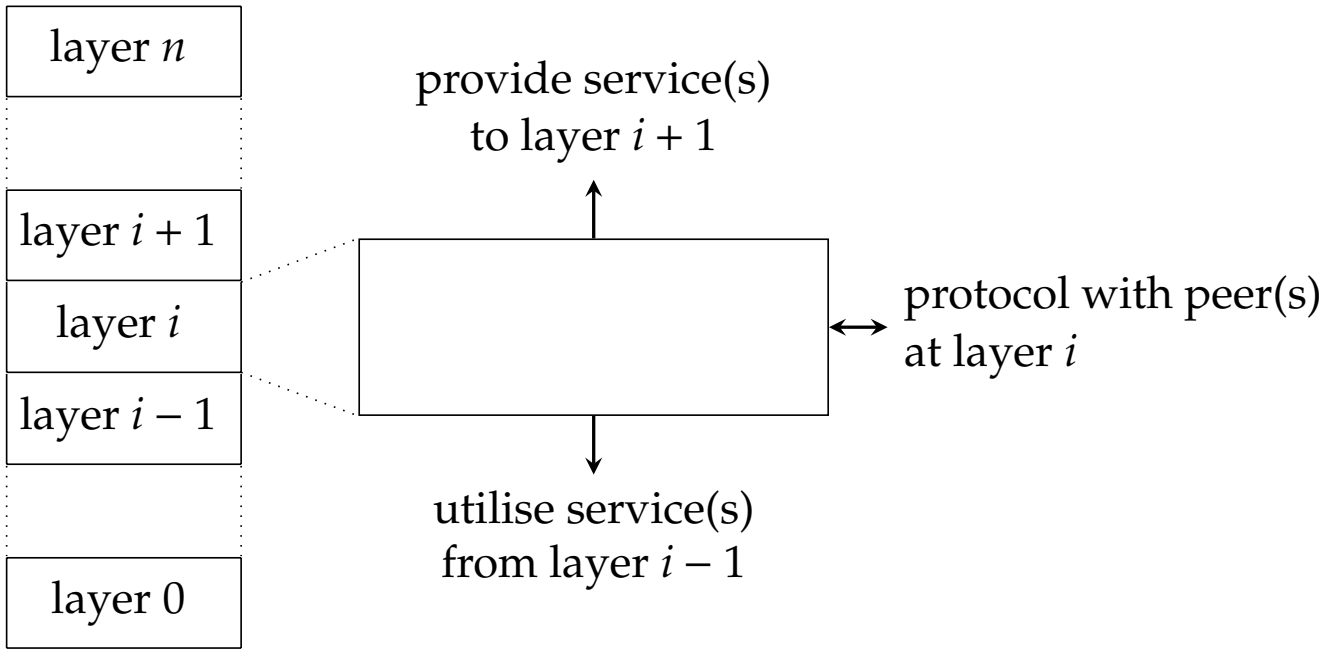
Problem #1: topology (6)

- An inter-network architecture seems a good approach!
  - Good:
    - scalable by virtue of a flexible and modular design, *and*
    - offers resilience against failure.
  - Bad: we need to cope with the fact
    - ideally we support a multiplicity of communication mediums and protocols, and share access to both,
    - each host needs a globally unique **address**, and
    - router(s) need to know or discover how to communicate (or **route**) data from one host to another

    the difficulty of which is enhanced by a need to avoid impact on scalability (e.g., avoid centralised solutions).

Problem #2: control (1)

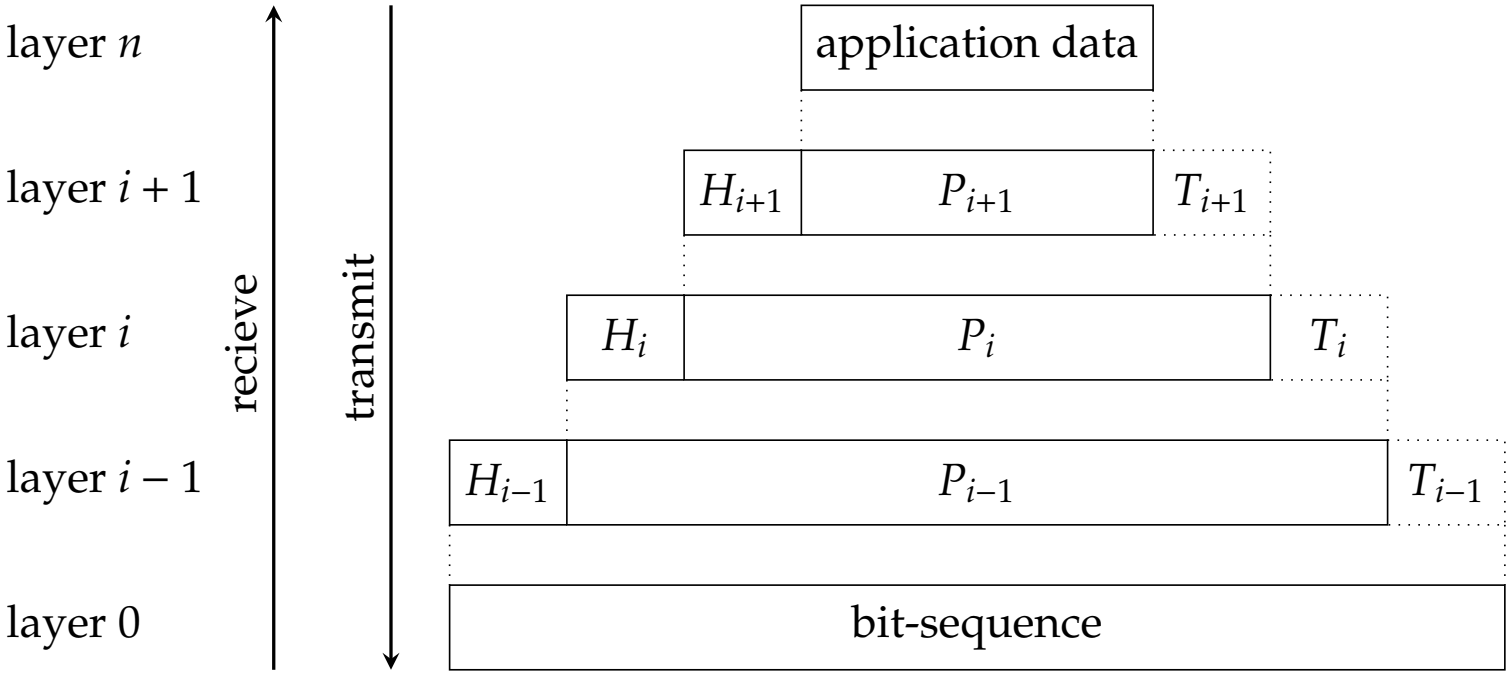
- Step #1: rather than use one monolithic protocol, decompose control, e.g.,



and hence provide various advantages stemming from modularity ...

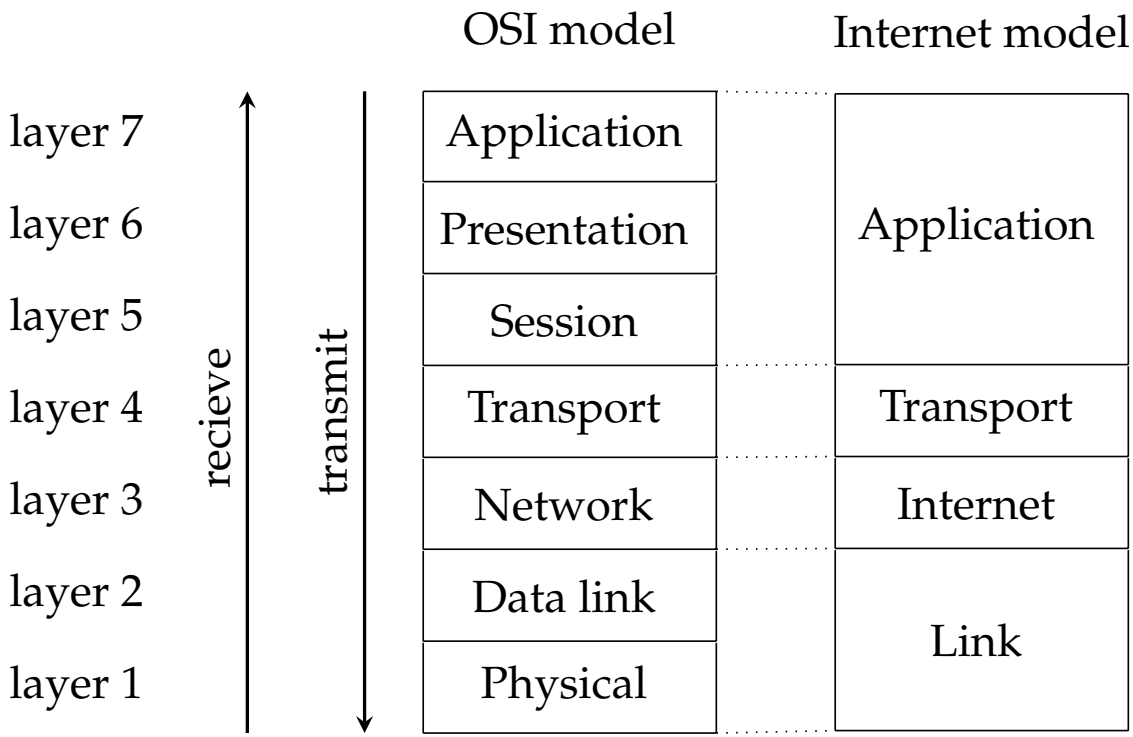
Problem #2: control (2)

- ... then support inter-layer (peer or otherwise) communication using **encapsulation**:



Problem #2: control (3)

- Step #2: specify (abstract) layers we need, e.g.,



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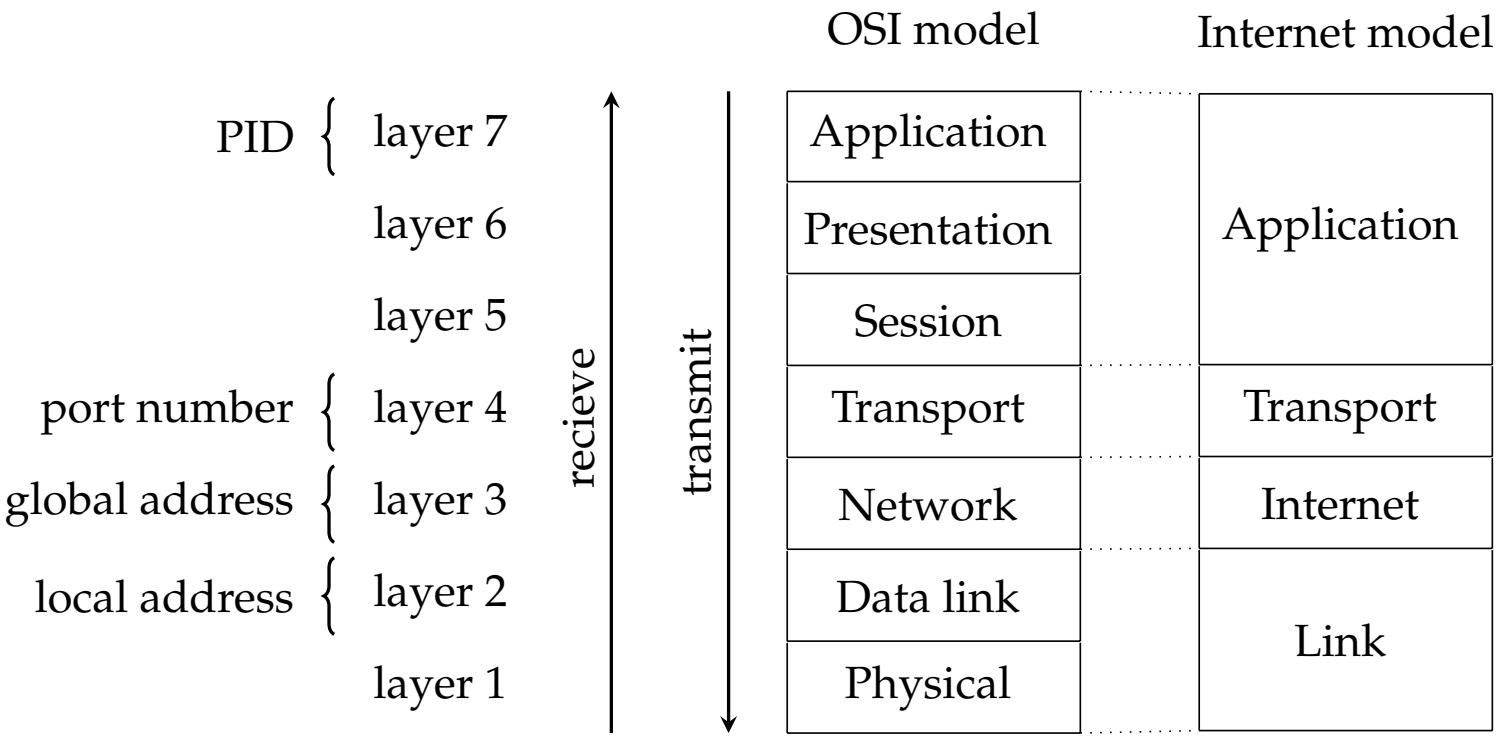

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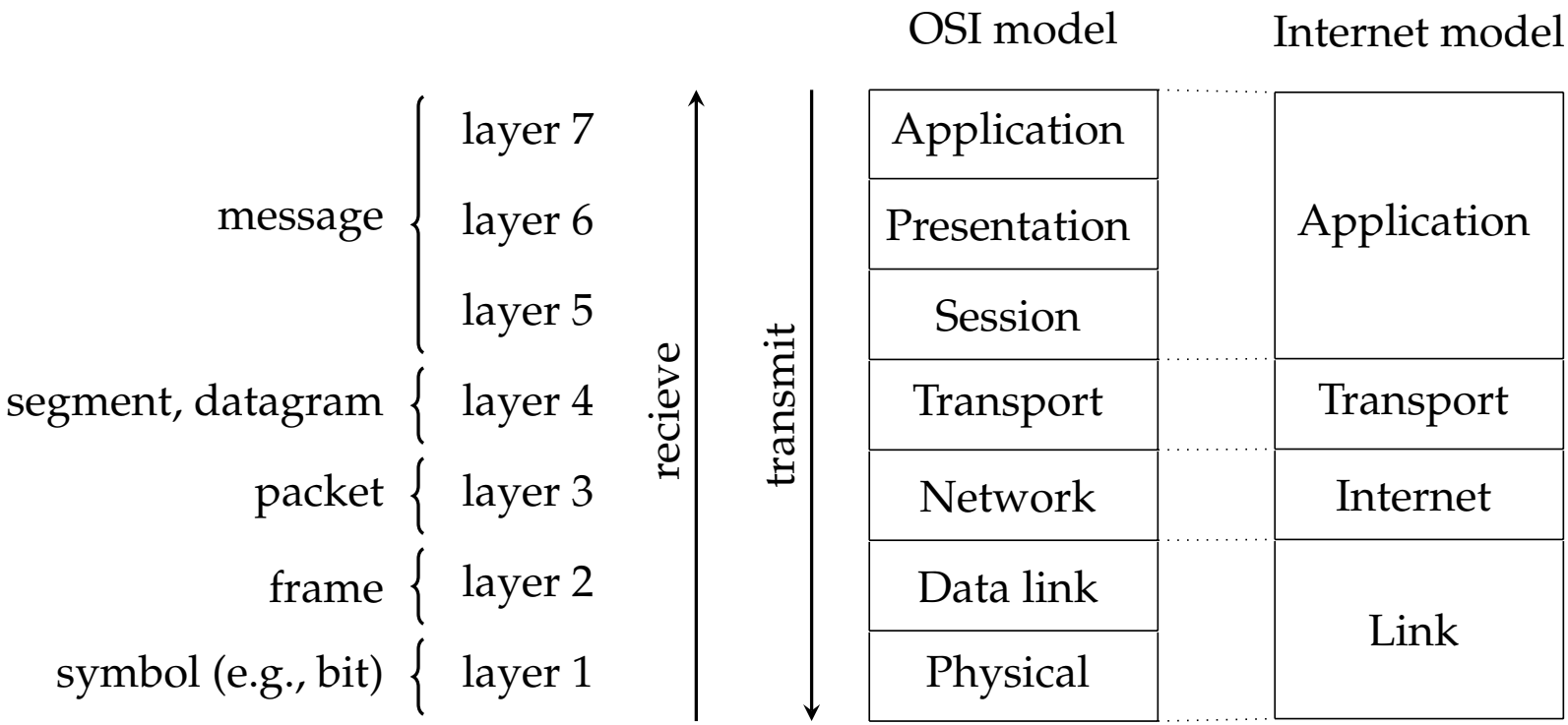

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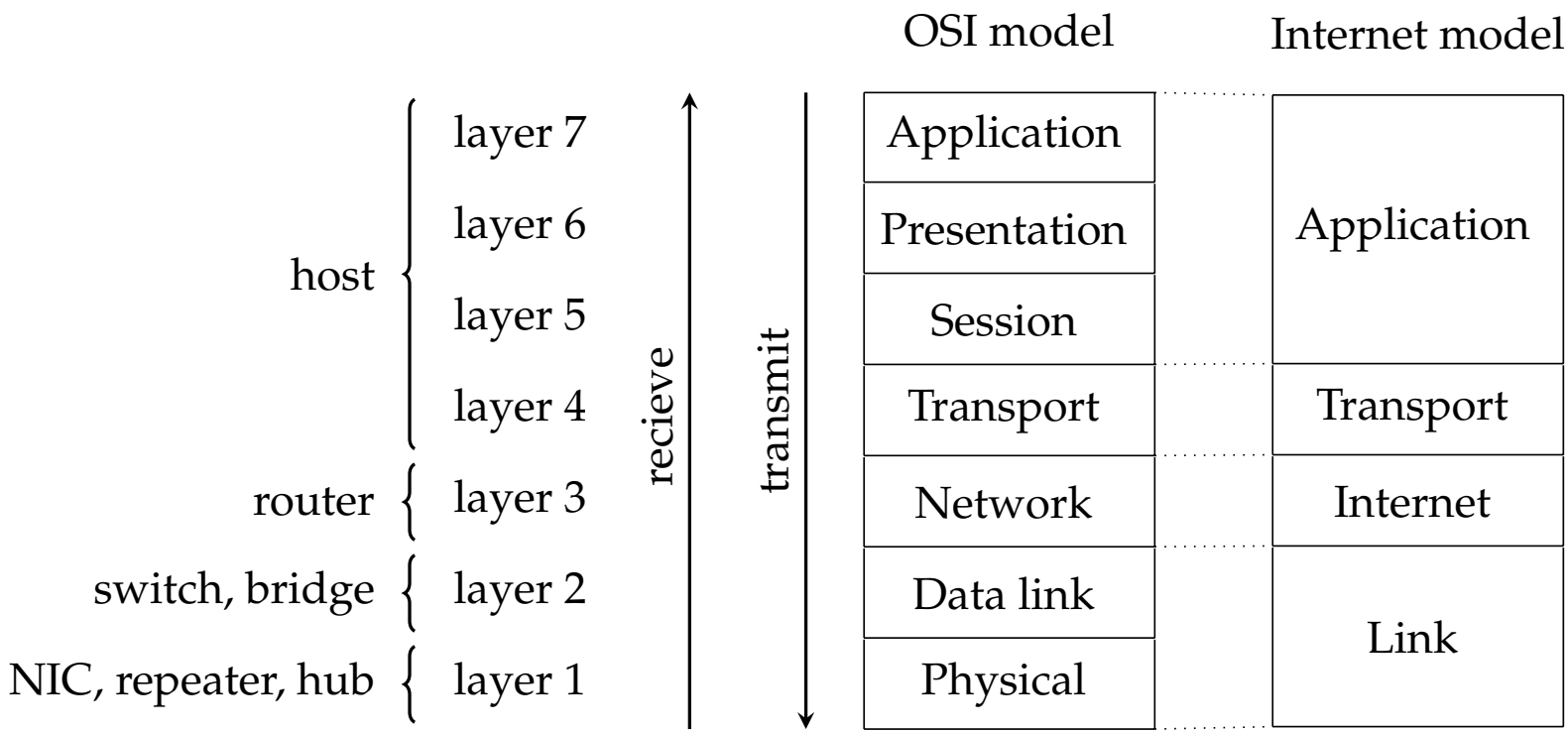

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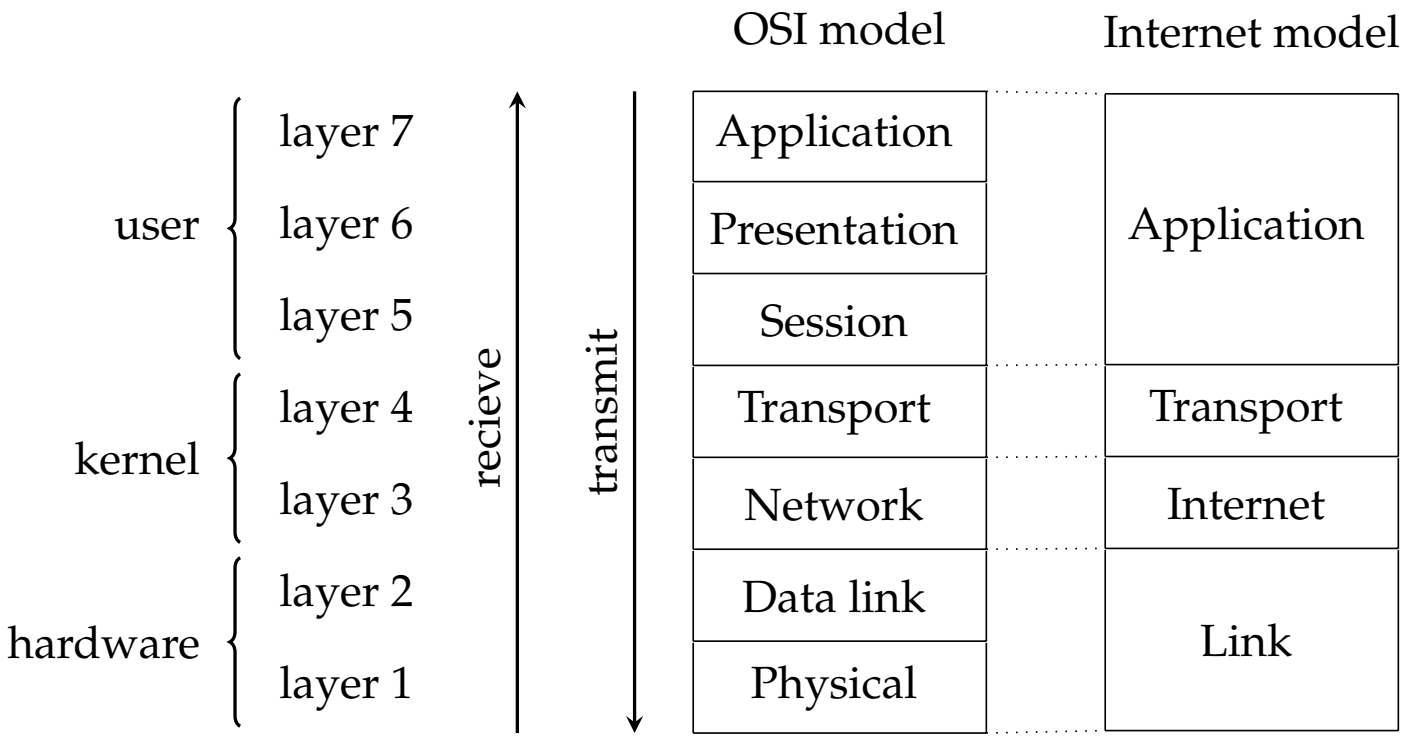
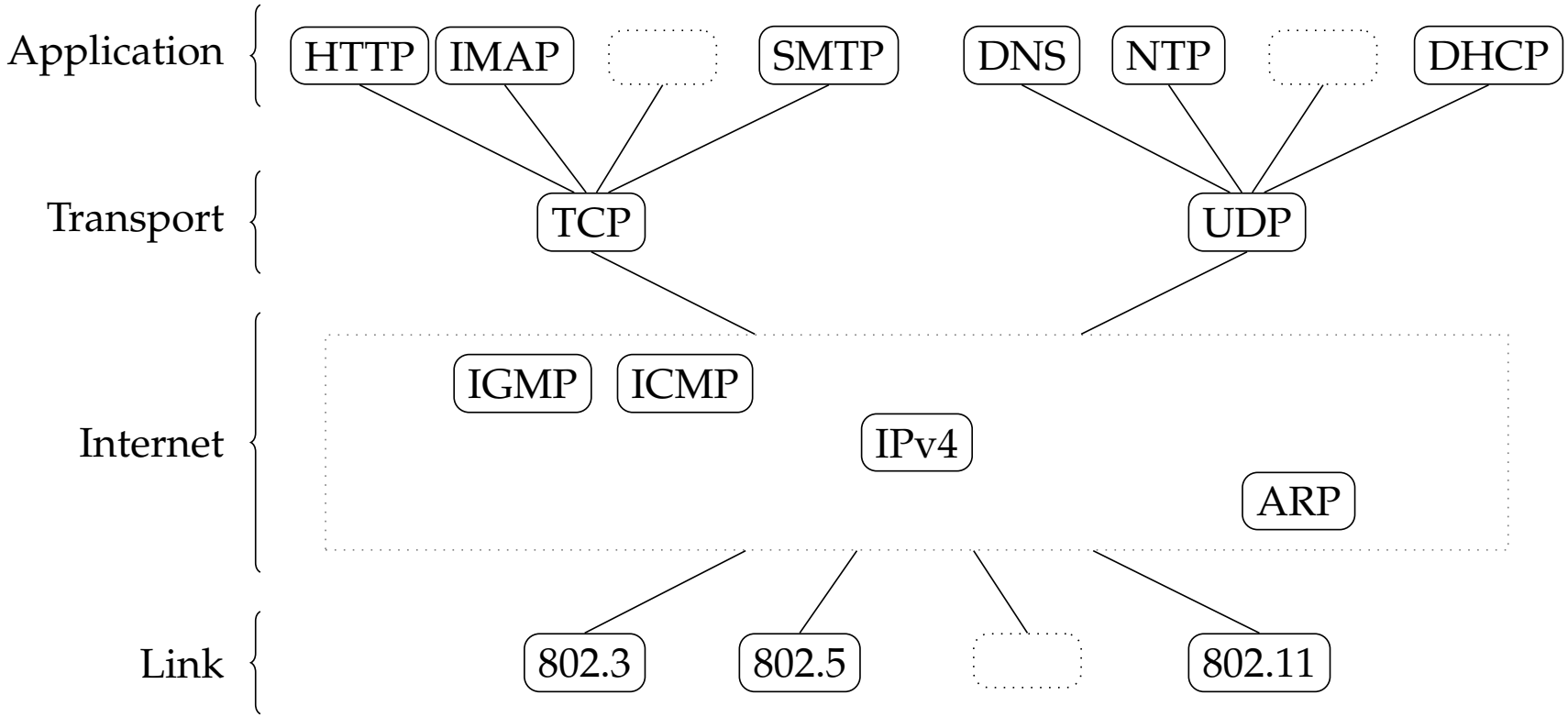


Problem #2: control (4)

- Step #3: populate layers with (concrete) protocols, e.g.,

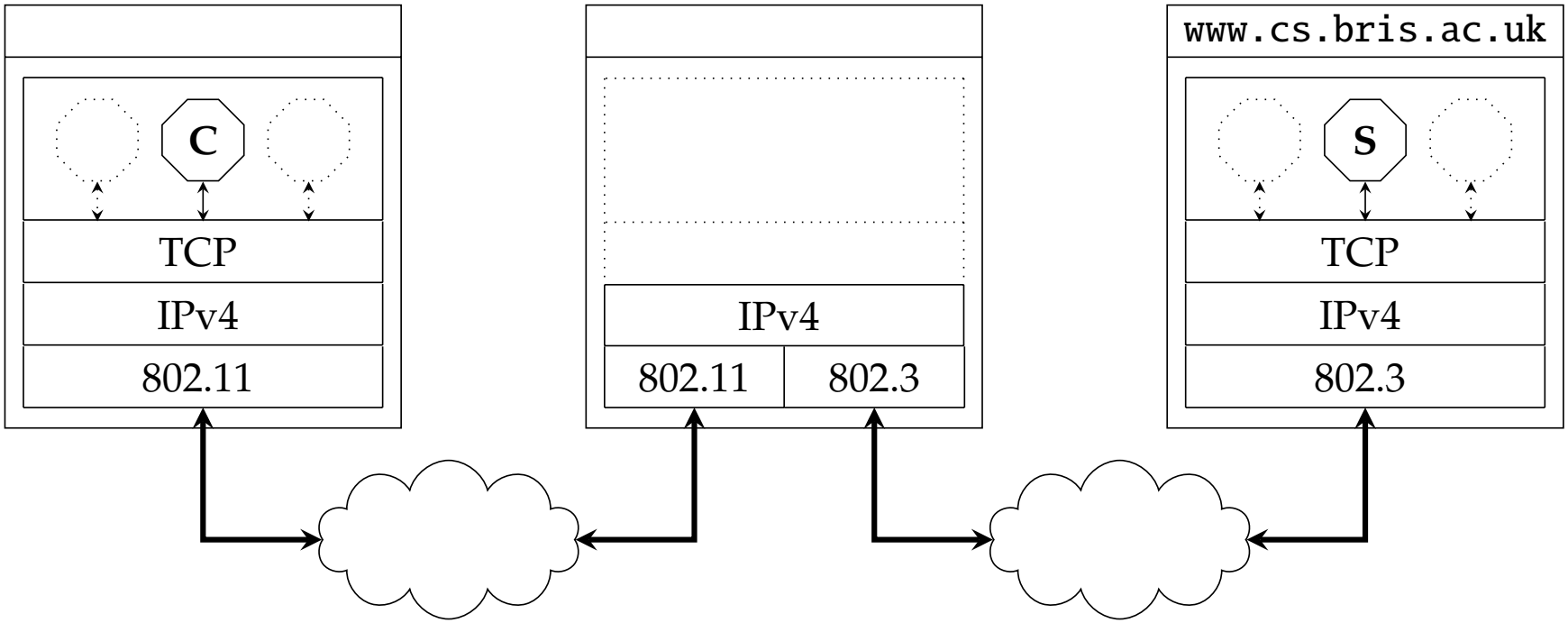


noting that

- a **protocol graph** is an abstract description of how protocols fit into the layered model, whereas
- a **protocol stack** is a concrete implementation of *one* top-to-bottom combination of protocols.

Conclusions

- As a final step, we can add some detail to our running example, e.g.,



with the rest of the unit aiming to further explain each layer.

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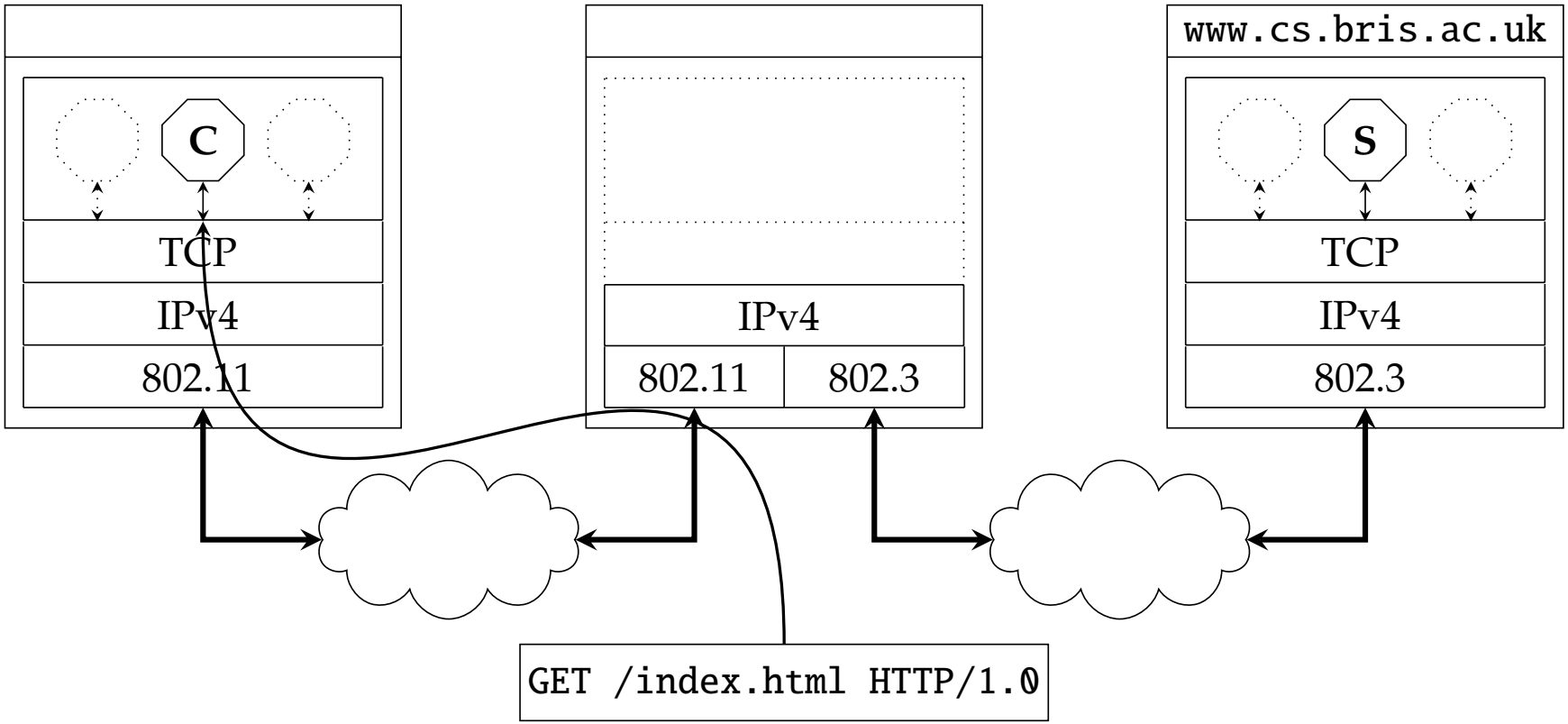

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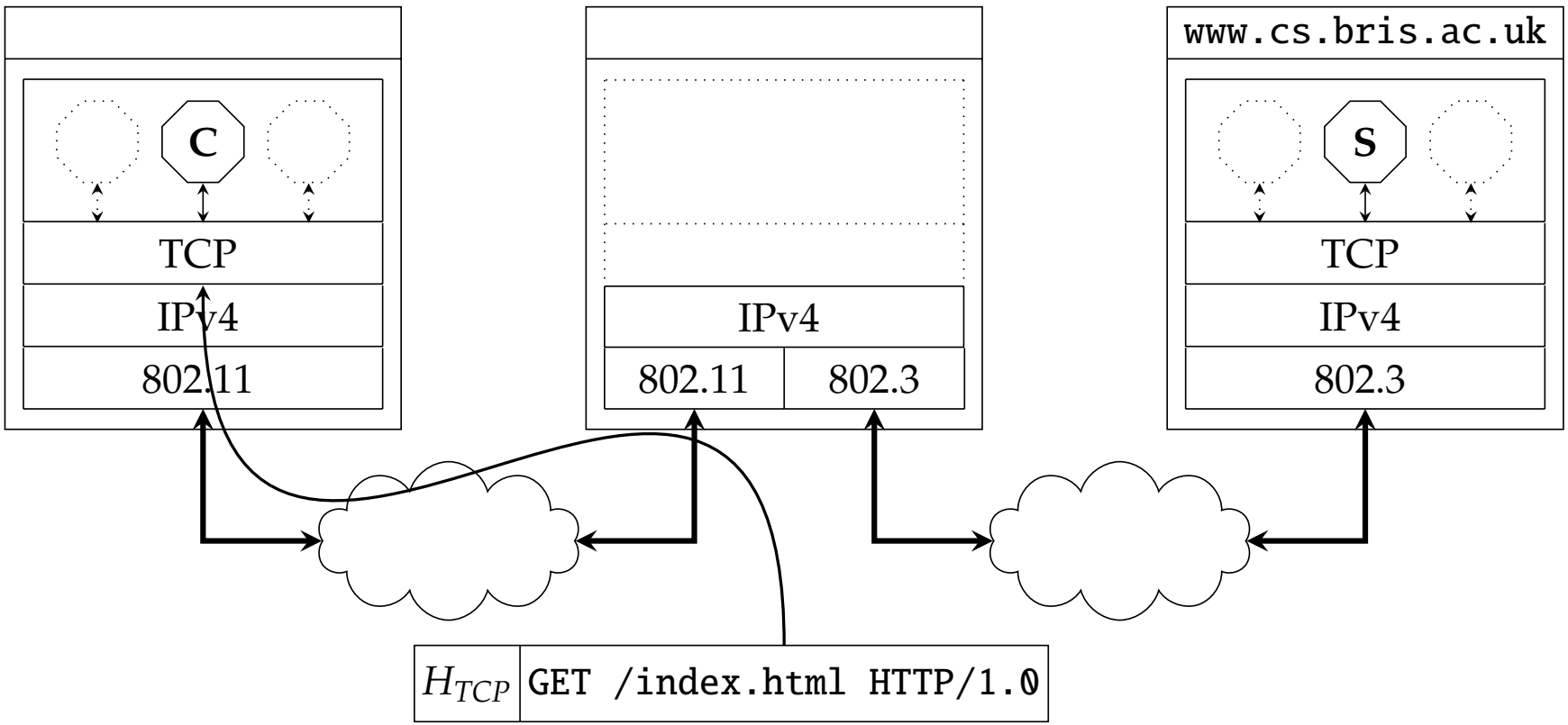

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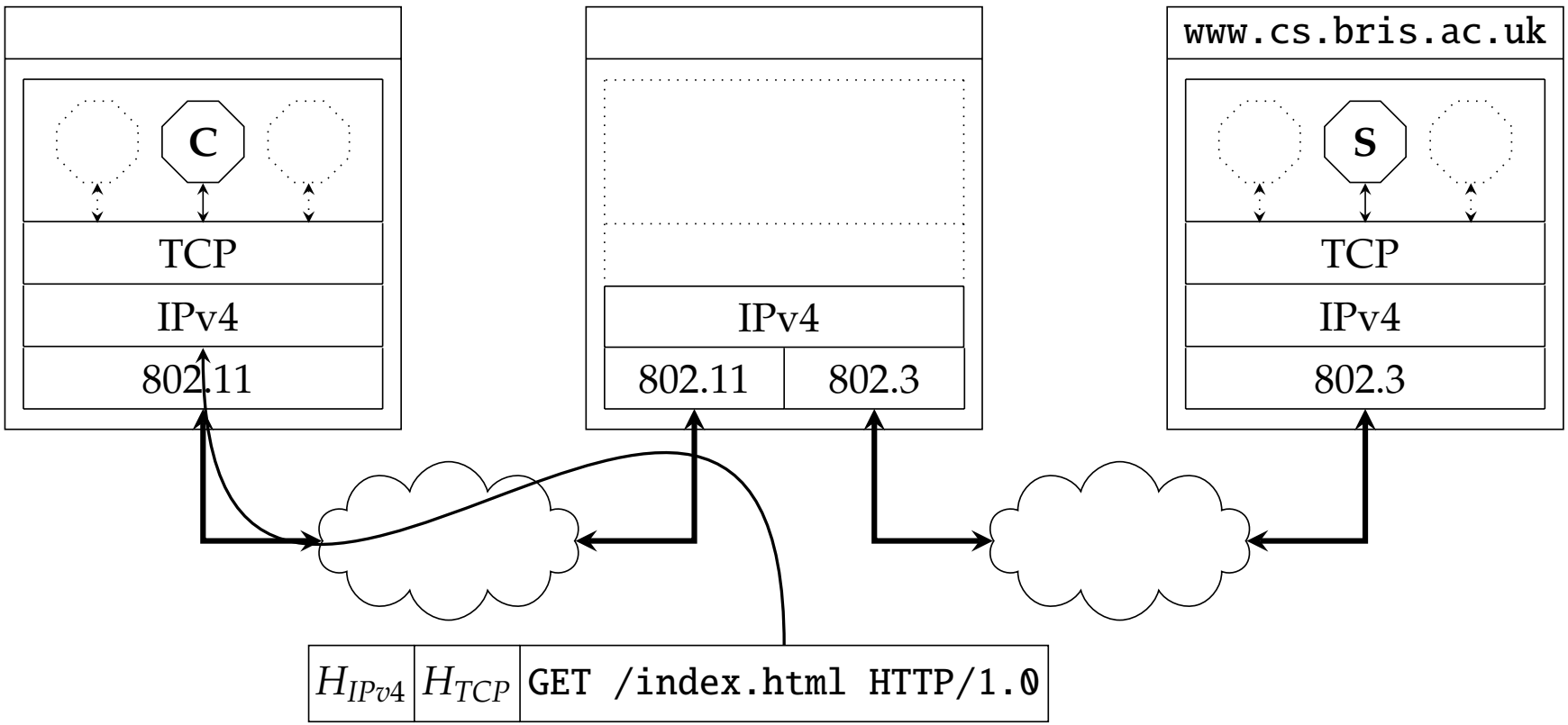

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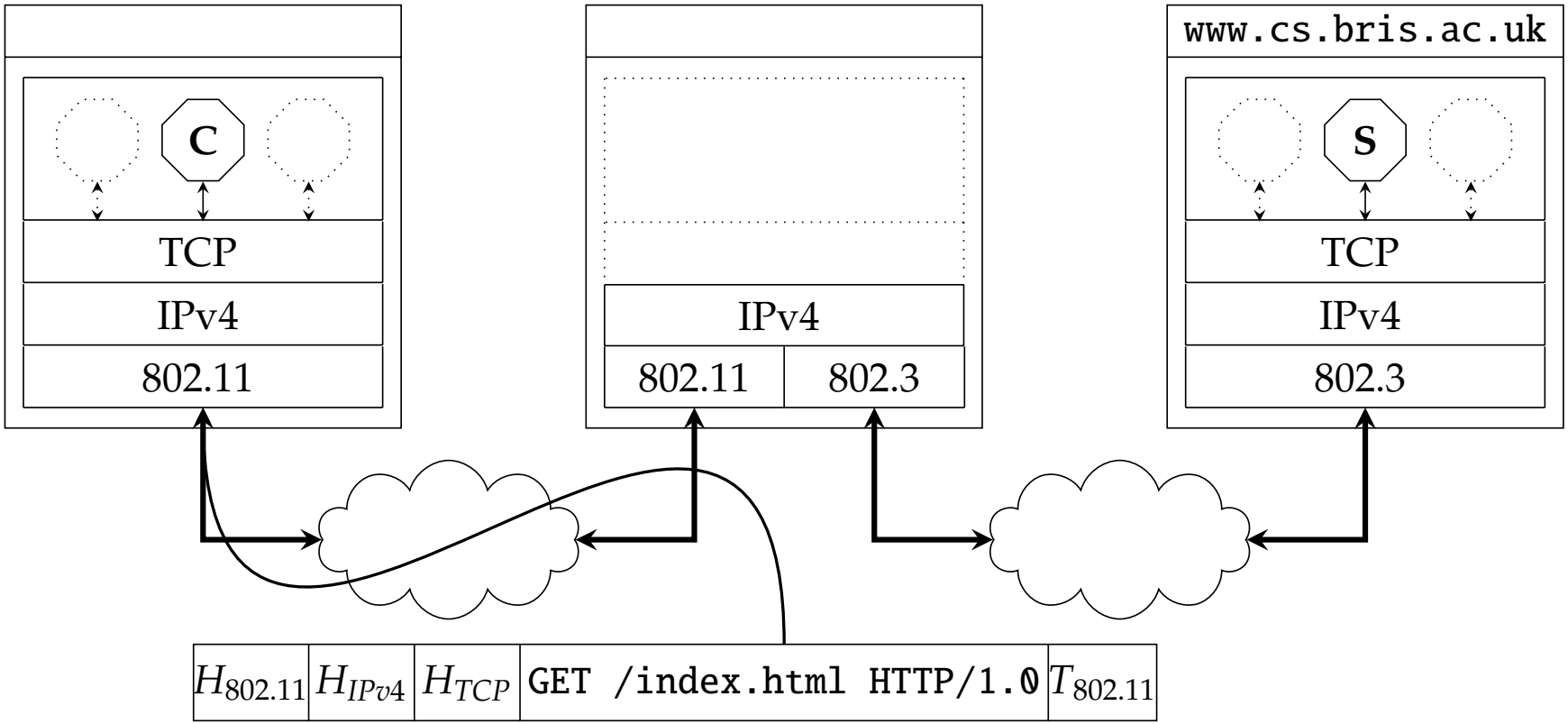

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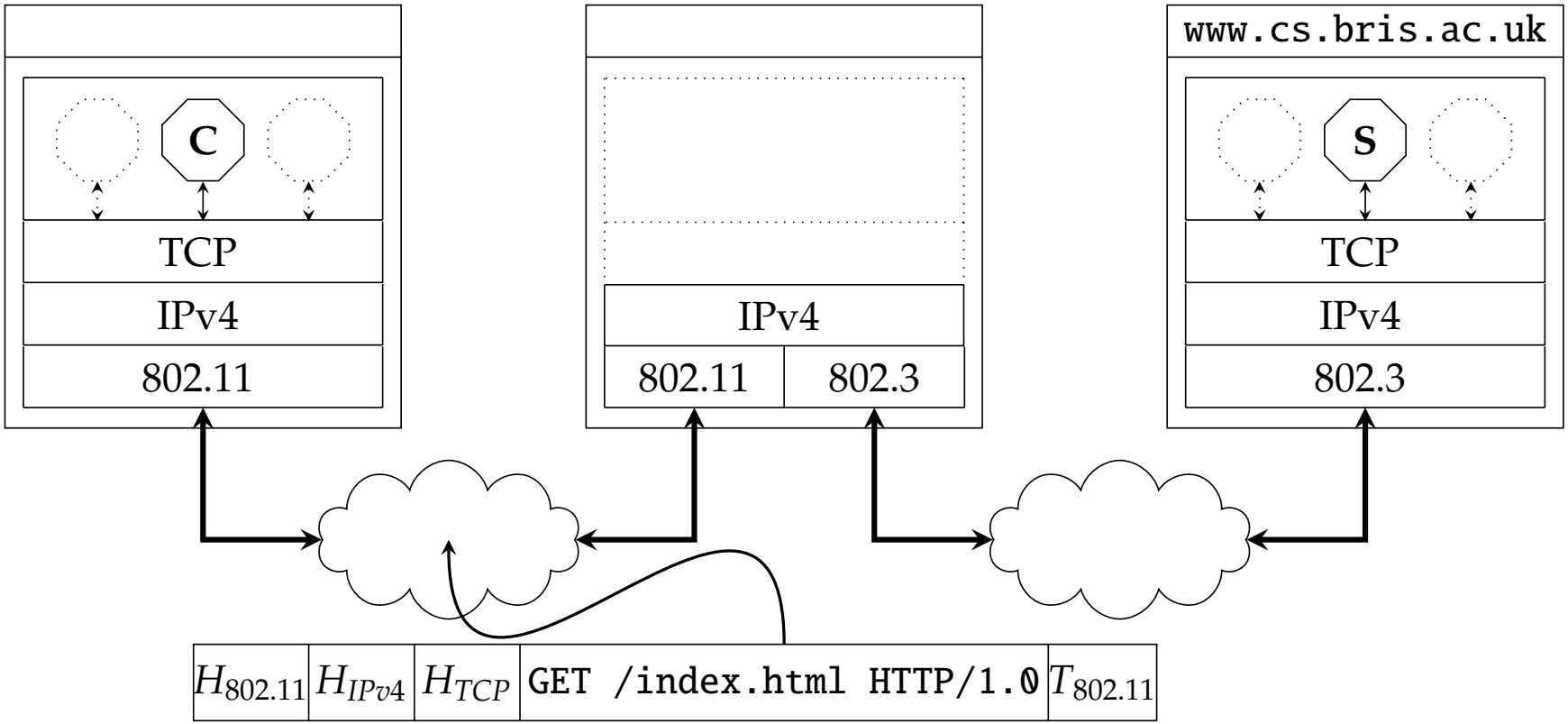

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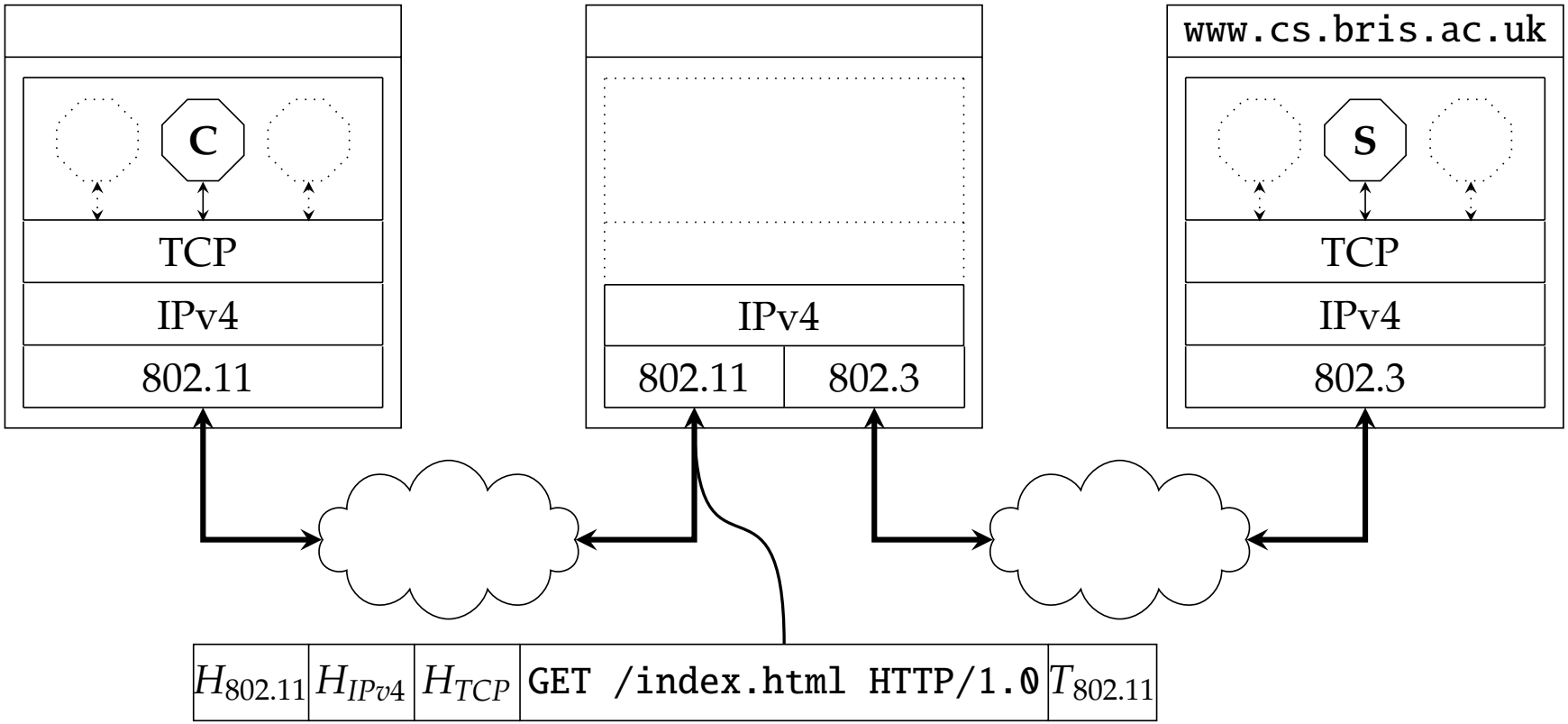

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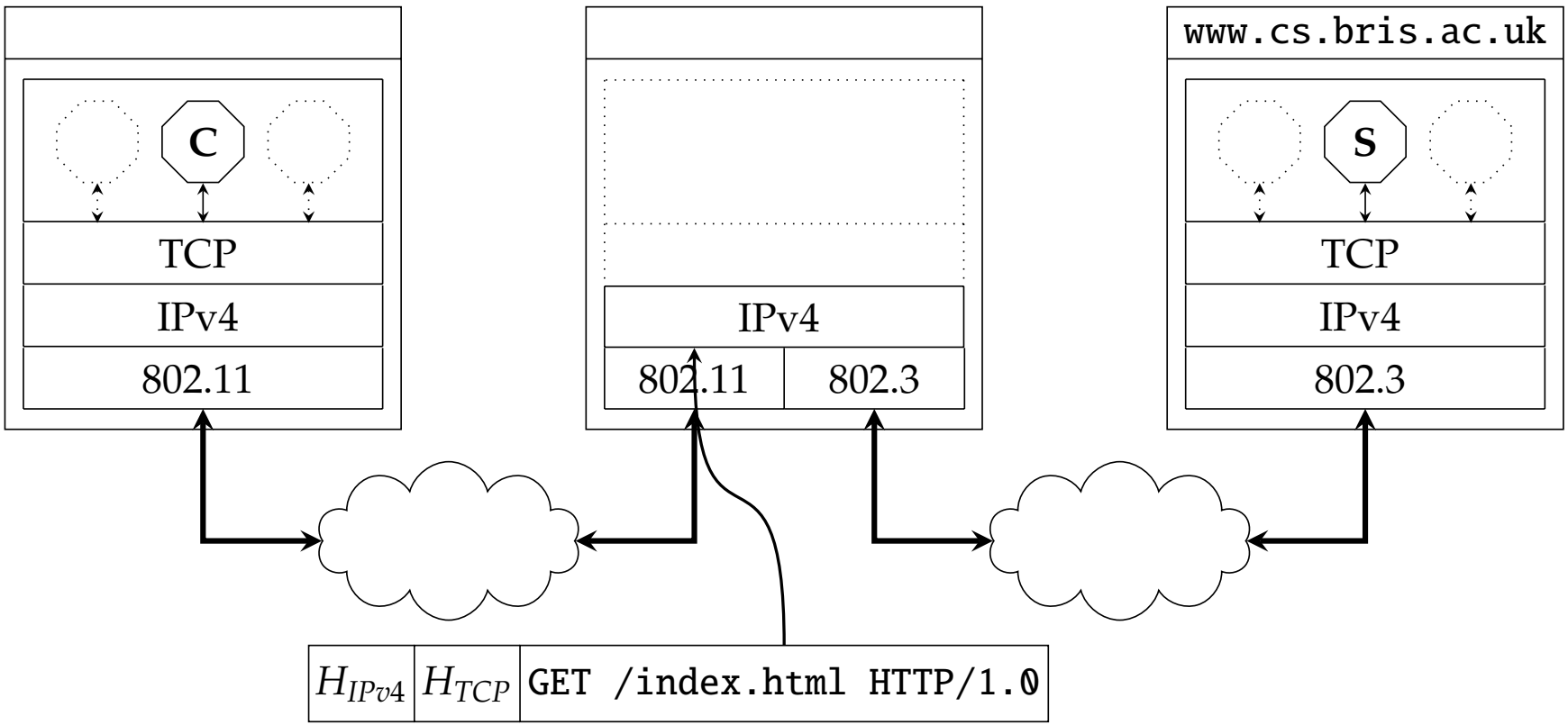

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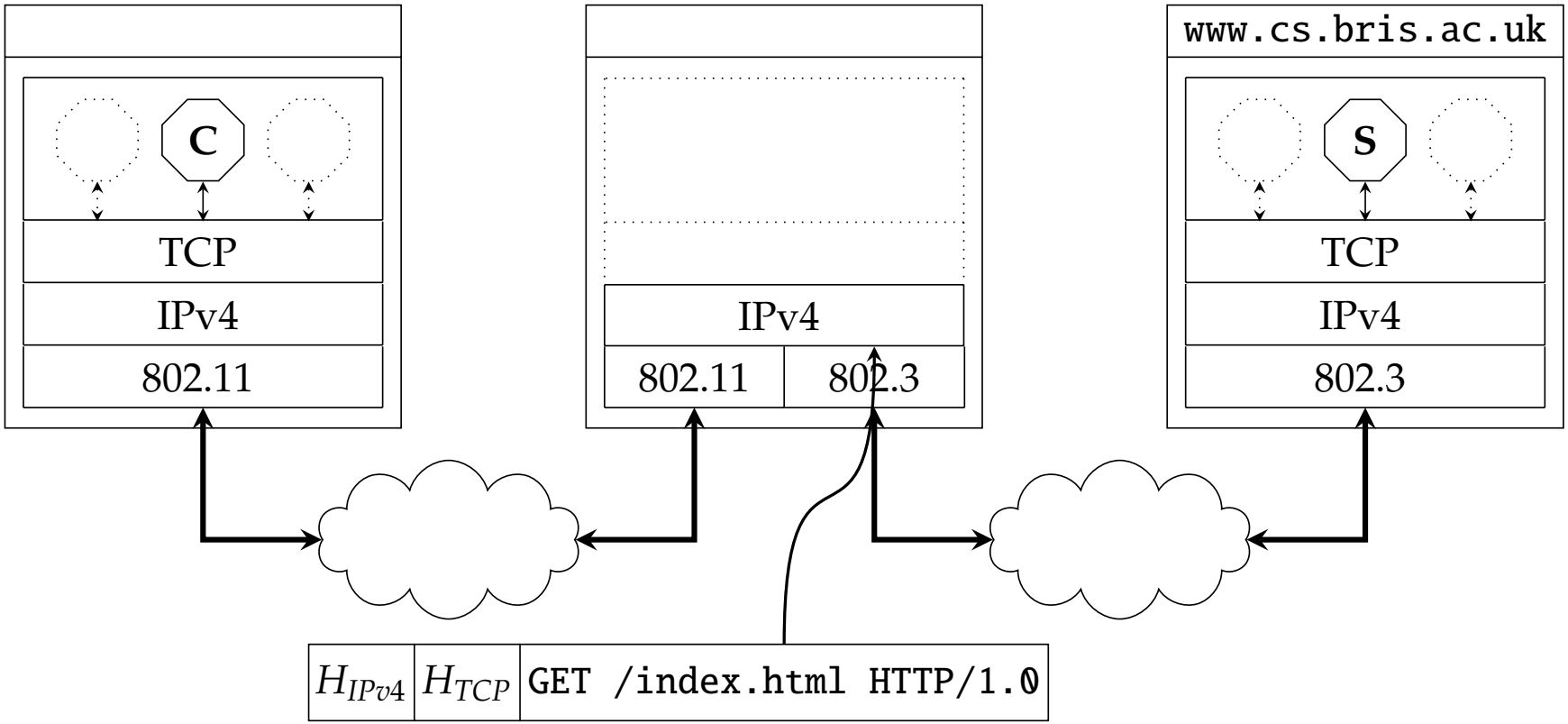

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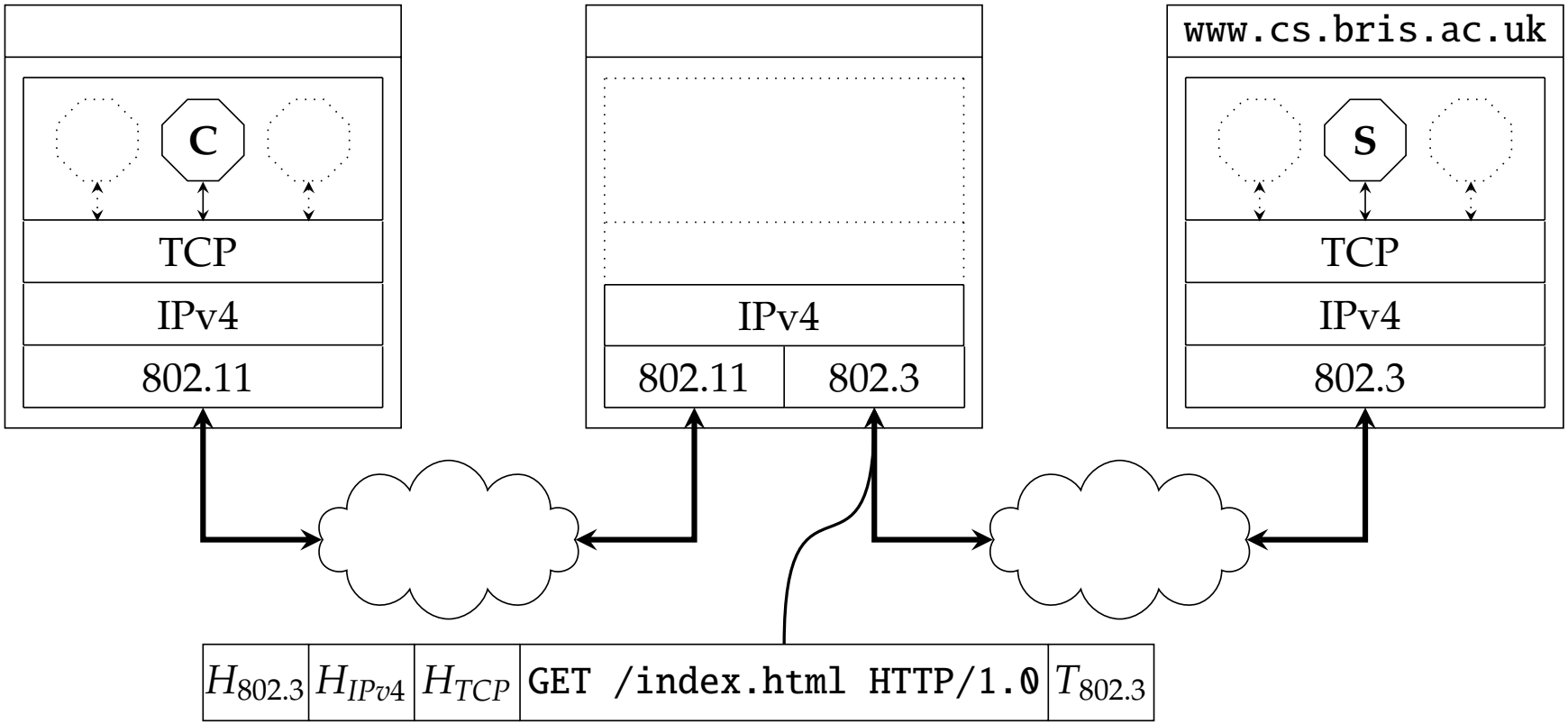

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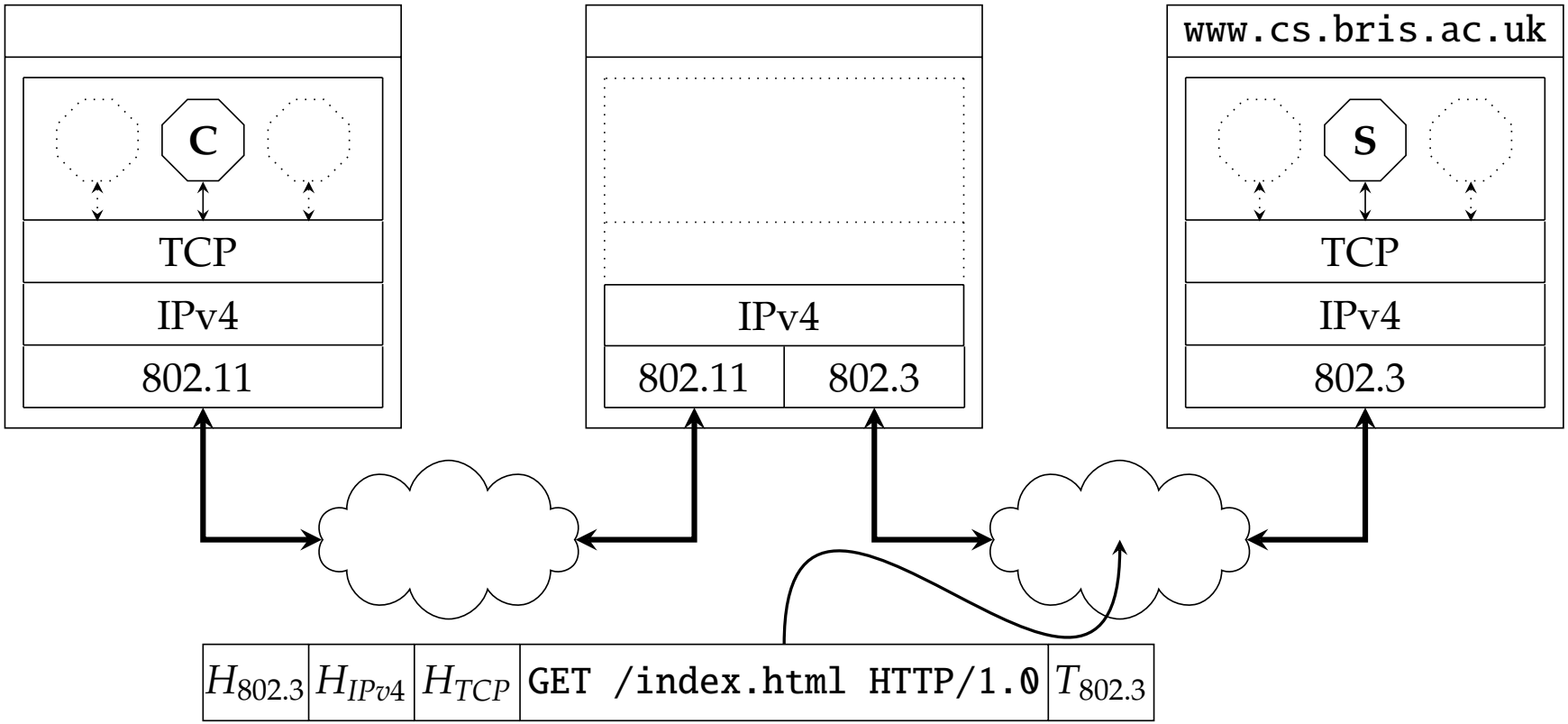

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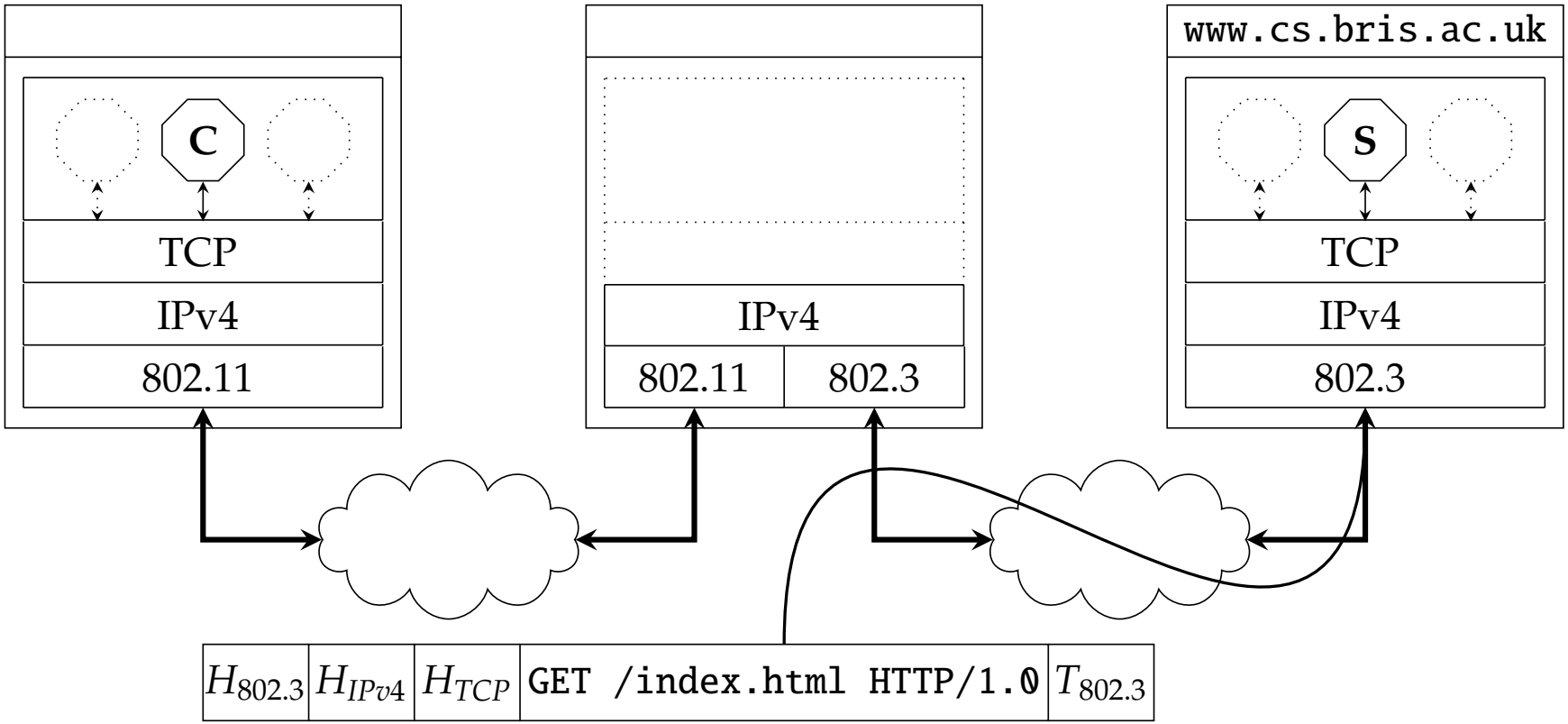

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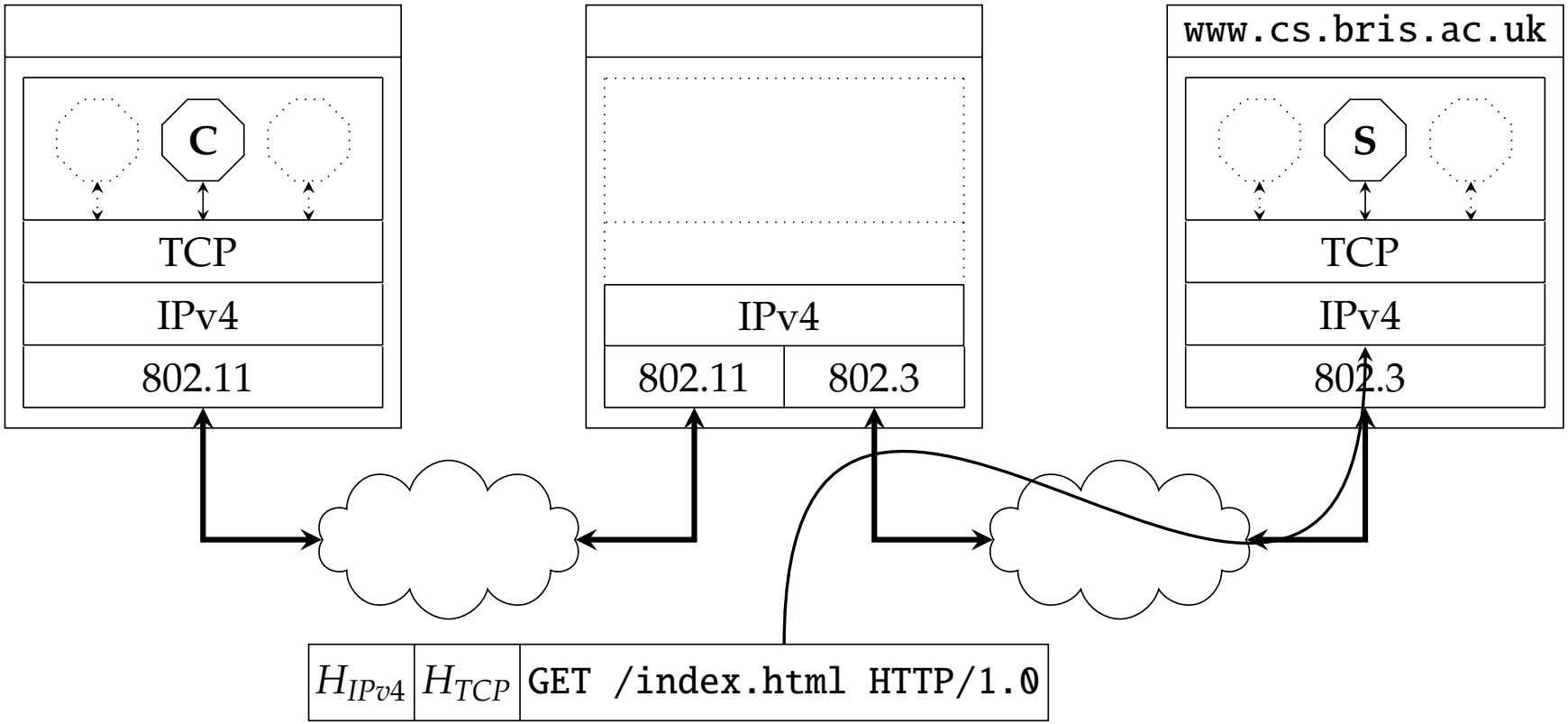

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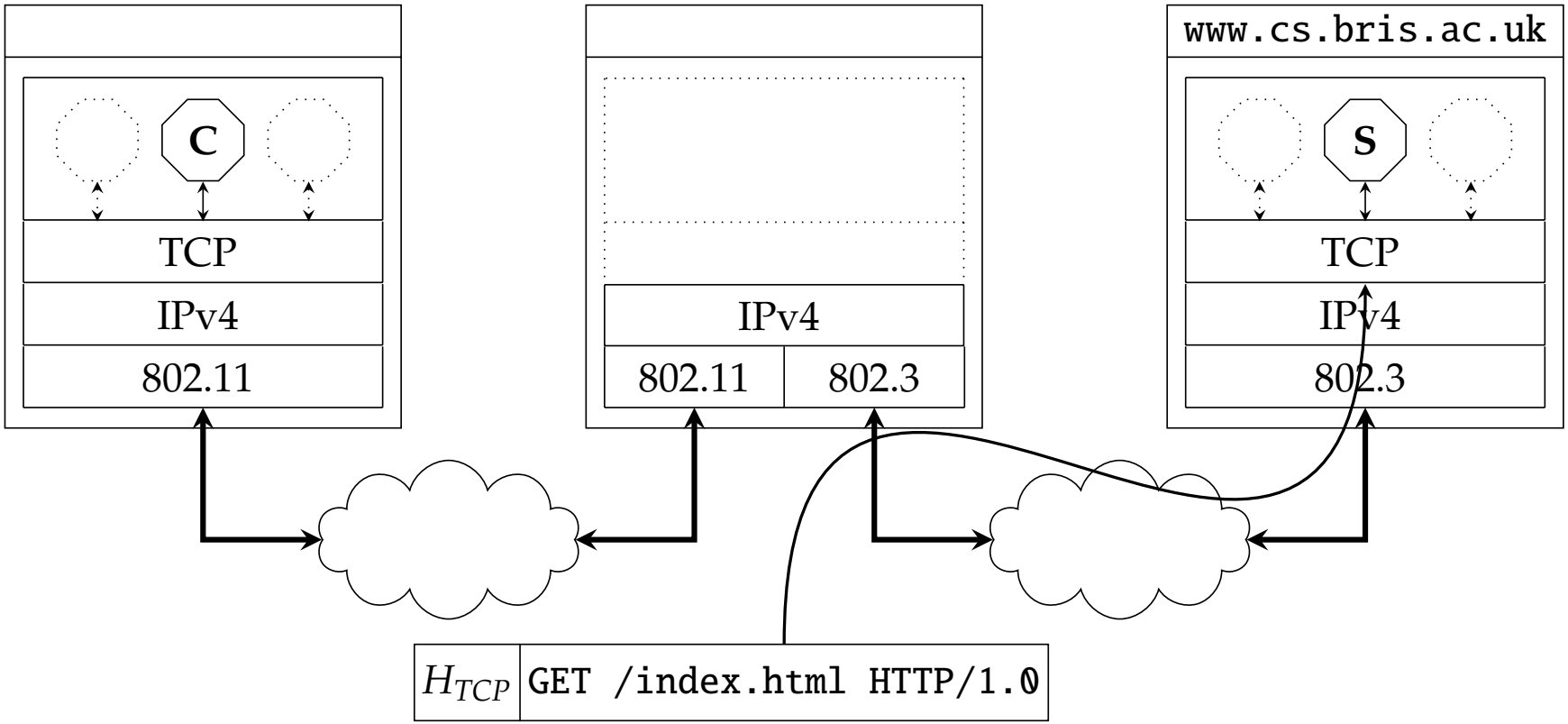

with the rest of the unit aiming to further explain each layer.

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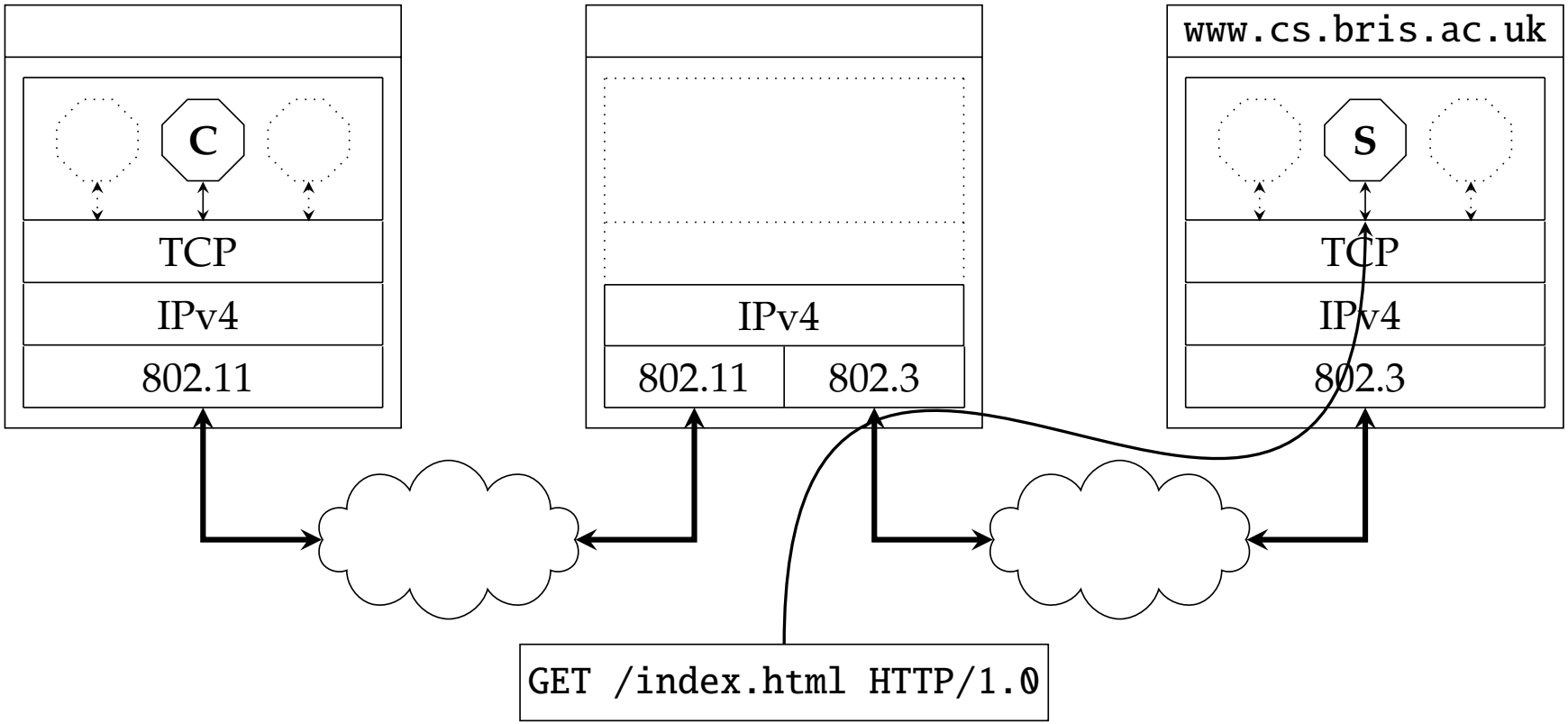

with the rest of the unit aiming to further explain each layer.

Conclusions

- Take away points:
  - Although a lot of this content might seem very abstract, the point is that we now have a sensible high-level design.
  - We'll fill in missing detail using a bottom-up approach by covering the
    1. link layer,
    2. internet layer,
    3. transport layer, and
    4. application layer

    while emphasising the *general* concepts as applied in specific technologies ...
  - ... keeping in mind the running, motivating example of HTTP.
  - A central challenge throughout is design of solutions that work efficiently in the general-case, but guarentee correctness in (many) special- or corner-cases.

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