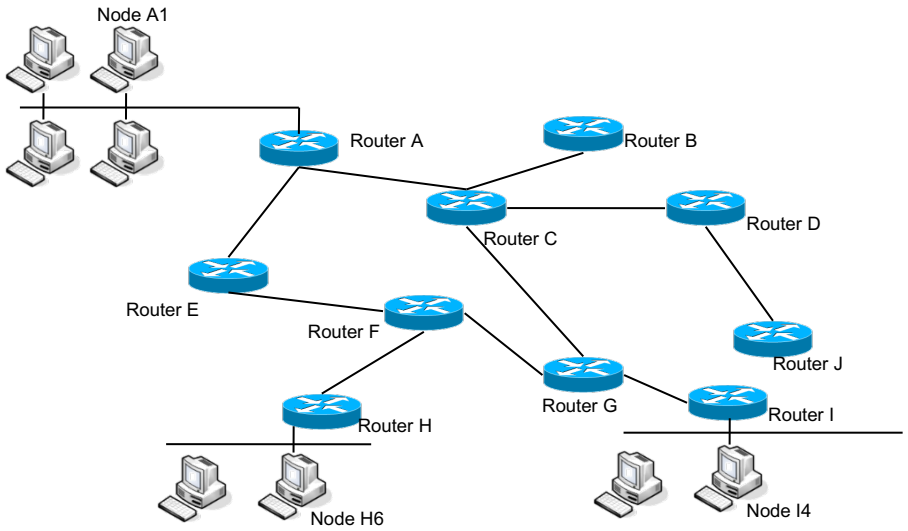
Multicast

1) Assume that the network below uses multicast routing in dense mode. Node A1, H6 and I4 subscribe to the address 224.0.0.1 and Node A1 sends a datagram to the address.

   a) Describe the initial communication between the nodes and the routers at their local network

   b) Describe the distribution of the datagrams between the source and subscribers and the potential pruning of the multicast tree, if Protocol Independent Multicast (PIM) in dense mode (DM) would be used in this network.

   c) Describe the distribution of the datagrams between the source and subscribers if Protocol Independent Multicast (PIM) in sparse mode (SM) would be used in this network.



   a) The nodes would use IGMP to inform the routers in their local network that they are interested in address 240.0.2.1 (join). The nodes should let the routers know, once they are not interested in receiving messages to this group e.g. when a program that was listening for these messages ends.

   b) In the case of PIM-DM, router A would broadcast the first transmission by A1 to all routers. In the next step, all routers that are not on forwarding paths – which is determined through a mechanism similar to the Spanning Tree algorithm – remove themselves from the tree for further broadcasts e.g. if router F would be selected as forwarder for routers H and G, all routers following and including router C could be removed from the forwarding path; router J would inform router D that it has no subscribers and would not be interested in further transmissions, router D would inform router C, router B would inform router C, and finally router

C would inform router A. Any further transmissions by A1 would be forwarded by router A only to router E.

c) In the case of PIM-SM, a router would need to be defined as rendezvous point (RP) for the network e.g. router C. Routers H and I would send a Join to the RP when they receive join messages from H6 and I4 respectively. A would register with the RP and transmit data to the RP and the RP would forward the data to routers that joined already. There is one optimisation in that Router F may discover that it is on a shorter path to A, the source of the data, compared to the RP and join A and prune itself from the distribution from the RP; however, the essential difference to PIM Dense Mode is that in Sparse Mode, a dedicated router, RP, is responsible for the distribution of data from a source, whereas Dense Mode relies on data being forwarded by routers and routers on networks with interested nodes pruning themselves from the distribution.

OpenFlow and Clos

1) OpenFlow v1.0 defines a format for flow table entries, shown in figure 2.
   i) Describe how these entries are used to direct traffic in a network with the help of an example.

   The fields of flow table entries are match against incoming packets, counters are increased for matching entries and then the actions of the matching entries are applied.

   ii) Discuss the limitations that this format may pose and suggest how these limitations may be addressed.

   The rule consists of fields for the incoming port on the particular switch, source and destination hardware addresses, ethernet type, VLAN ID, source and destination IPv4 addresses, and source and destination TCP port. This version was limited to the support of IPv4 and TCP and did not have fields that could be matched for example to IPv6 or UDP.

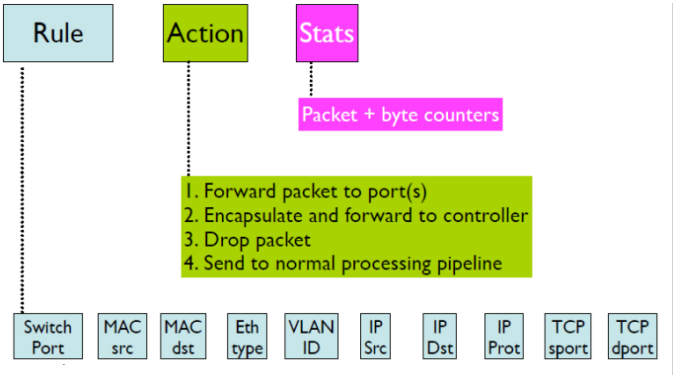


Figure 1: OpenFlow Flow Table Entry

2) Discuss the types of OpenFlow messages that are exchanged at the beginning of a connection between an OpenFlow switch and a controller and the types of message that is issued by a controller to modify a flow table in an OpenFlow switch.

Assuming that a controller exists in a given network and that an OpenFlow switch starts in this network with a configuration for the controller, the switch will send a Hello message to the controller and the controller will respond to this with its own Hello message.

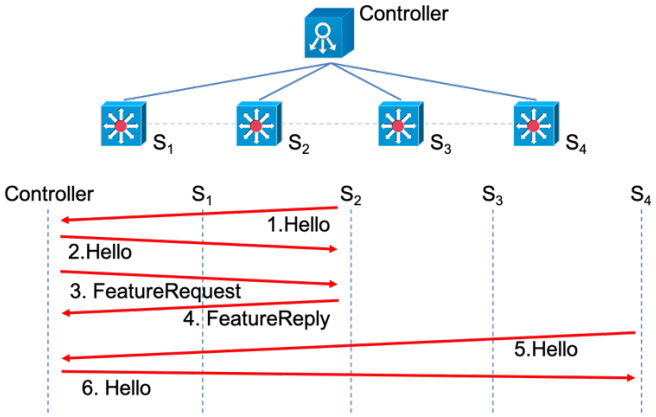


Figure 2: Example of a message exchange between OpenFlow switches and a controller, beginning with an exchange of Hello messages, followed by a FeatureRequest message from the controller and a FeatureReply from a switch.

3) Explain the advantages and disadvantages of a data centre where the hardware of the data centre may consist of 512 racks using a fat-tree topology in comparison to a traditional 4-post router approach.

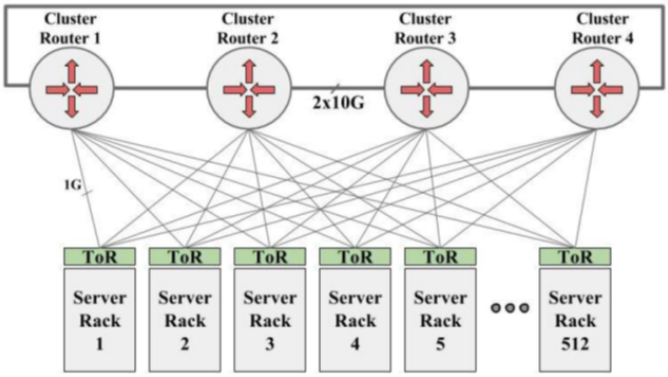


Figure 3: Data centre scenario with 512 racks and 4 routers*

In a 4-post router topology, the connections from top-of-rack switches to router are limited and this may lead to the competition by various flows for the use of these connections. The move from a 4-post router topology to a fat-tree topology increases the number of possible paths between servers in a rack to other server. This increase in potential paths and multiple devices in aggregation and spine blocks provides alternative paths that can be exploited to avoid competition for the use of individual connections.

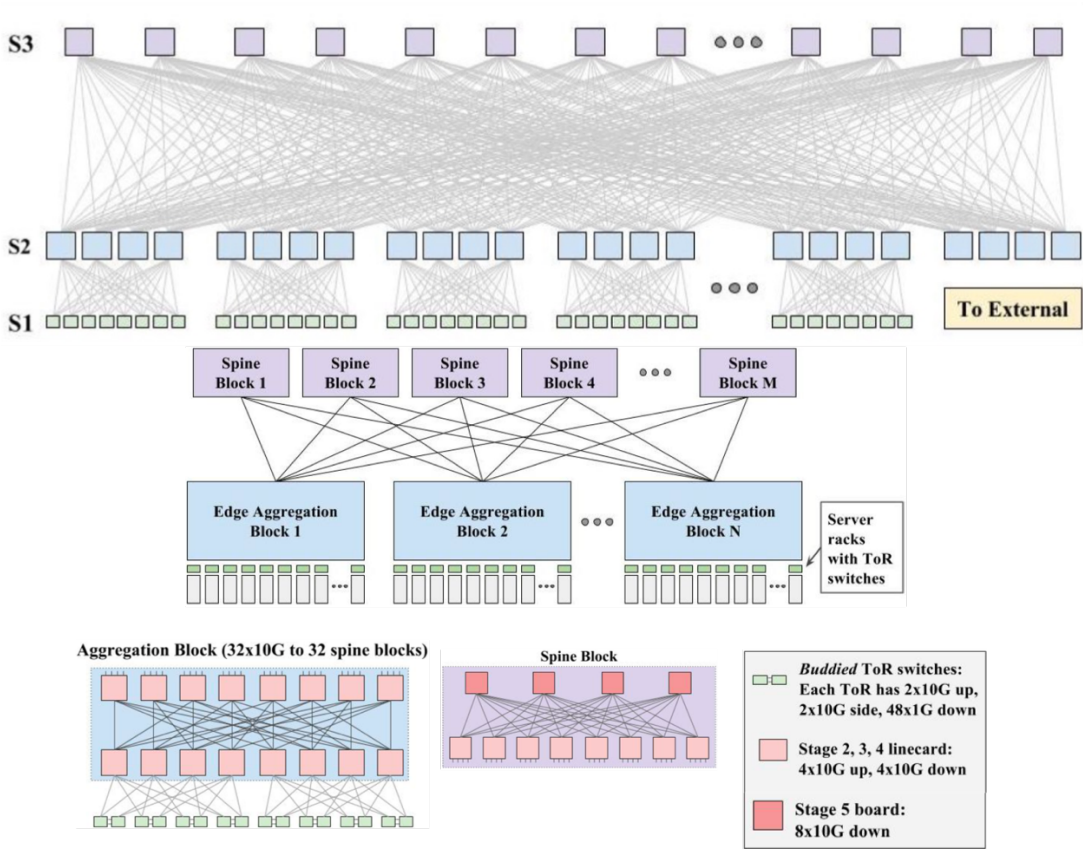


Figure 4: The diagrams above give an overview of the increase of links between network elements in comparision to a 4-post router topology.