IPv6

1) IPv6 describes the next version of Internet Protocol that was designed to replace IPv4. Describe the concepts that were introduced with IPv6, contrast them with the concepts in IPv4 and discuss 3 improvements of IPv6 over IPv4.

   IPv6 introduced amongst other concepts Anycast, Extension Headers, Auto-Configuration, Dual Stack Implementations and the split of addresses into link-local, site-local and global addresses. See the textbook for descriptions of these concepts.

   IPv6 improvements over IPv4 include larger address space by using 128-bit addresses, simplified headers by removing the need for fragmentation, extension headers in order to allow introduction of functionality to adapt to new requirements.

2) Discuss the two proposed formats of addresses for IPv6 and contrast them with the adapted format of addresses for IPv6.

   During the development of IPv6, two particular formats were proposed: One with fixed 64-bit addresses and one with flexible addresses with up to 160 bits. The advantage of the fixed addresses of 64 bits is that hardware could be developed to analyse addresses for routing. The disadvantage of fixed 64-bit addresses would be that the address space may become overpopulated again and lead to an address shortage in future. Flexible addresses would have the advantage that they could be adapted to future requirements and situations with a variety of requirements; however, the interpretation of flexible addresses for routing may be more time intensive and slower. The 128-bit address format of IPv6 has the advantage that it is a fixed address size, avoiding some of the effort that is necessary to interpret flexible addresses and it offers 64 bit more address space than the proposed 64-bit address space. The disadvantage of this approach may be that a 128-bit address is too large to be exploited efficiently and leads to avoidable overhead. One could argue that a 64-bit address space for a network ID would have been sufficient and that a flexible-size host ID would offer the option to adapt host IDs to various requirements.

OpenFlow and Clos

3) 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.

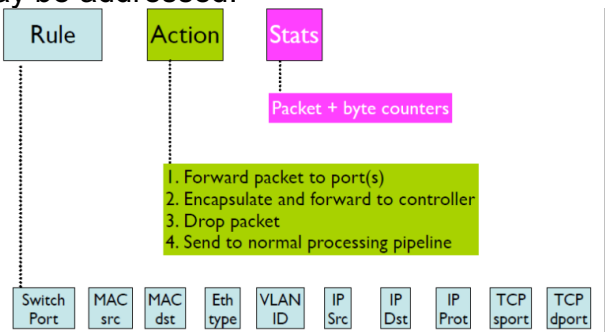

Figure 1: OpenFlow Flow Table Entry

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.

4) 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.

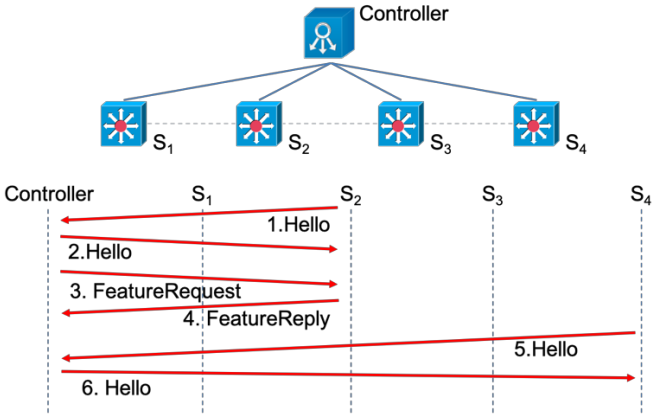

Figure 2: Example of a message exchange between OpenFlow switches and a controller, beginning with an exchange of Hello messages, followed by a FeatureRequest message from the controller and a FeatureReply from a switch.

5) 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.

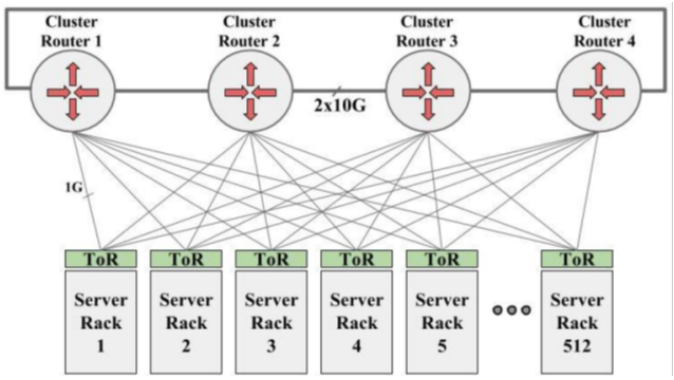

Figure 3: Data centre scenario with 512 racks and 4 routers*

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.

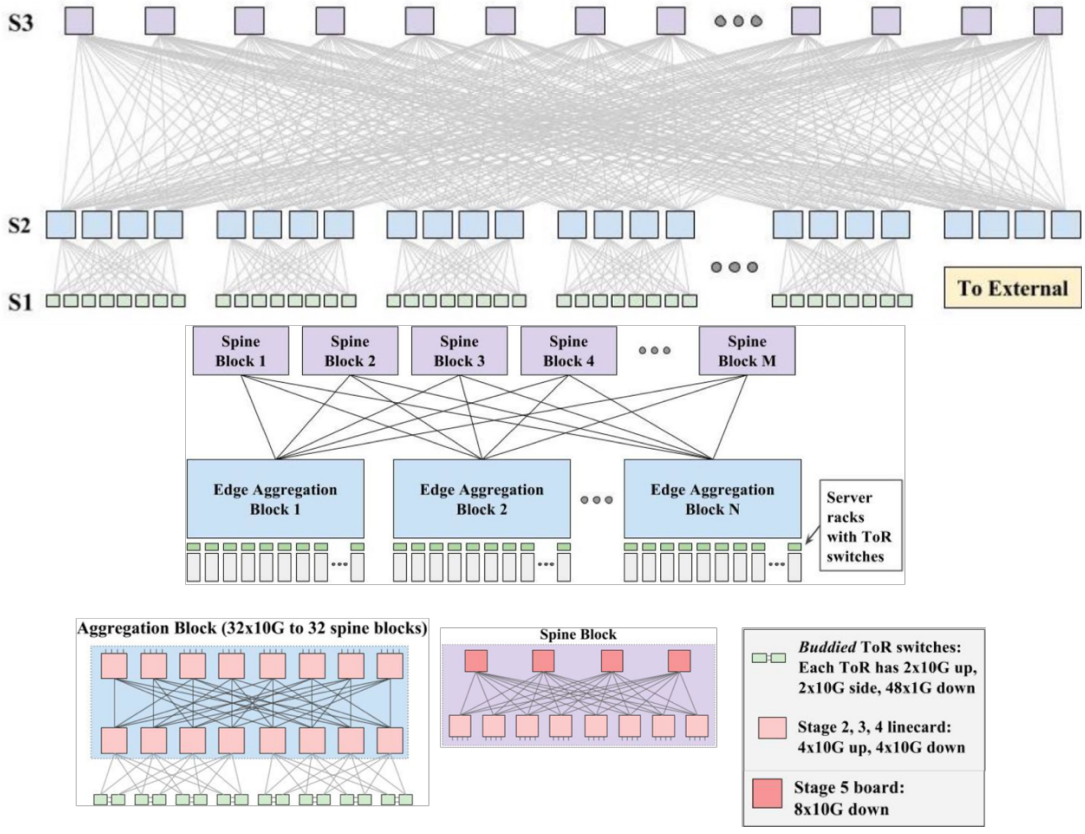

Figure 4: The diagrams above give an overview of the increase of links between network elements in comparision to a 4-post router topology.