Given: Base HTML file, $5 \times 10^3 \times 8$ bits, and 8 referenced objects, each $200 \times 10^3 \times 8$ bits, on the same server. Control messages are 200 bits each. Client and server are connected with $TR = 10 \times 10^6 \times 8$ bits per second in both directions. Non-round trip propogation delay is 50 ms. How long to retrieve objects:

Thus, we know the Non Round Trip Time for each Control request is

$$T_{CONTROL} = \frac{200}{8 \times 10^7} + (50 \times 10^{-3}) \text{ seconds} = 0.0500025 \text{ seconds} = 50.00025 \text{ ms}$$

And that each TCP request/response is

$$RTT_{TCP} = 2T_{CONTROL} = 100.0005 \text{ms}$$

The amount of time to transmit the base HTML file is (not including file request):

$$T_{HTML} = \frac{5 \times 10^3 \times 8}{8 \times 10^7} + (50 \times 10^{-3}) \text{ seconds} = 0.0505 \text{ seconds} = 50.5 \text{ ms}$$

The amount of time to transmit each object is (not including file request):

$$T_O = \frac{200 \times 10^3 \times 8}{8 \times 10^7} + (50 \times 10^{-3}) \text{ seconds} = 0.07 \text{ seconds} = 70 \text{ ms}$$

A: Using non-persistent HTTP with no parallel connections Aka HTTP 1.0. There is a seperate TCP connection for each object.

$$T = \sum_{i=1}^{9} RTT_{TCP} + T_{CONTROL} + T_i$$

$$= 9(RTT_{TCP} + T_{CONTROL}) + T_{HTML} + 8(T_O)$$

$$= 9(100.0005 + 50.00025) + 50.5 + 8(70) \text{ ms}$$

$$= 1960.00675 \text{ ms} = 1.96000675 \text{ s}$$

B: Using non-persistent HTTP with parallel connections There is a seperate TCP connection for each object. Base HTML file must be received before objects are requested. Afterwards, we can run each item in parallel. Time to receieve the base HTML file:

$$T_{Base} = RTT_{TCP} + T_{CONTROL} + T_{HTML}$$

$$= 100.0005 + 50.00025 + 50.5 \text{ ms} = 200.50075 \text{ ms}$$

Next, we calculate time for each object opening 8 parallel connections, with $TR_p = \frac{1}{8} \times TR$. So the new T_O is:

$$T_O = \frac{200 \times 10^3 \times 8}{10^7} + (50 \times 10^{-3}) = 210 \text{ ms}$$

Since we run all objects in parallel, the final time is:

$$T = T_{Base} + T_{CONTROL} + T_O = 460.501 \text{ ms}$$

C: Using persistent HTTP, no pipelining or parallel connections
HTTP 1.1. Allows for multiple HTTP requests to be sent over the same TCP connection. Can only send new requests once previous request was received (non-pipelined). Non parallel.

$$T = RTT_{TCP} + 9(T_{CONTROL}) + T_{HTML} + 8(T_O)$$

$$= 100.0005 + 9(50.00025) + 50.5 + 8(70) = 1160.50275 \text{ ms} = 1.16050275 \text{ s}$$