Server – Web Client system. Figure 3 represents a residential client 56 kbps modem connection and round-trip-time (RTT) of 310 msec. In the absence of other background traffic, the bottleneck link is the client network connection. Several different connections and network properties were considered that correspond to low bit rate operational environment as perceived by people through a home Internet connection. Therefore the bandwidth between Web Client and node N2 was set-up with different values between 28 kbps and 128 kbps while the RTT between the Web server and the Web client was considered to be between 530 msec and 150 msec respectively.
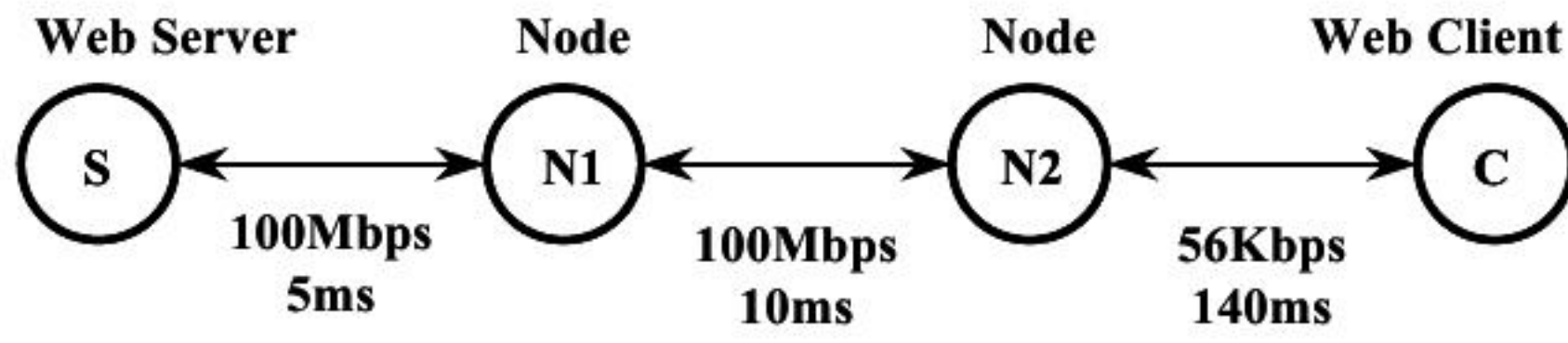
Web Server   **Node**   **Node**   **Web Client**

S — 100Mbps 5ms — N1 — 100Mbps 10ms — N2 — 56Kbps 140ms — C

Figure 3. NS-2 Simulation Topology

A browsing session that consists of ten Web pages was simulated. Two types of network conditions involving constant and variable network parameters (e.g. bandwidth, RTT) during the simulated browsing session were analysed. The Web pages are randomly selected, based on the SURGE technique, from a virtual Web site located on the Web Server. The Web site is populated with one hundred pages randomly generated. These pages have different properties such as Web page size, number of the embedded objects per page and size of each embedded objects. The Web pages were generated using the NS-2 Web Generator, based on a The Pareto-II probability distribution. This distribution best simulates the characteristics of the Web server resources, the distribution of a Web object size on a Web site and it is the most used function for Web traffic simulations.

Table 2 Parameters of Distribution Function of the Web Page Characteristics

Web Content Characteristics	Probability Distribution parameters
Basic Page Size	Pareto-II Distribution with $avg = 3000B$, $shape = 1.2$
No. of Embedded Objs per Page	Pareto-II Distribution with avg = 4, $shape = 1.5$
Embedded Objects Size	Pareto-II Distribution with $avg = 4500$, $shape = 1.2$
Pages per Web Server	100

Table 2 presents Pareto-II Distribution parameters setup used during the simulations. *Shape* parameter was setup according to the Web traffic specifications presented in the NSWEB [25] documentation. *Avg* parameter was set based on the results of research [26] that analysed and characterised Web pages from most popular Web sites based on the amount of content of a page, the number of bytes in the basic Web page, the number of embedded objects and the total number of bytes for the embedded objects. The results presented in [26] have shown that most of the Web pages would have the size of the basic page up to 12 KB, an average of 7 up to 20 embedded objects and the total size of the embedded objects around 55 KB or higher.

4.2 Assessment of the QoE – based Adaptation Mechanism in Constant Low Bit Rate Operational Environment

The simulations involved various Web sessions with different sequences of ten Web pages randomly selected from a virtual Web site populated with one hundred pages. In this paper we present the results for one set of ten pages selected from the virtual Web site. The characteristics of the selected pages are presented in Table 3. Six types of low bit-rate environments characterised by different network conditions (Table 4) were simulated.

Table 3 Characteristics of ten pages randomly selected from a virtually generated Web site

Web Page ID	Basic Page Size (KB)	Number Of Embd. Objects	Total Size Of Embd. Objs (Kb)	Total Size Of Web Page (KB)
1	9.18	8	82.39	91.57
2	3.10	8	57.96	61.06
3	3.17	6	93.96	97.13
4	10.80	8	190.22	201.02
5	5.61	6	37.73	43.34
6	3.42	9	169.01	172.43
7	12.24	5	64.37	76.61
8	9.38	7	57.68	67.06
9	5.4	10	134.32	139.72
10	3.38	5	36.30	39.67

Table 4 Simulated low bit rate operational environments

Connection Type	Bandwidth (kbps)	RTT (msec)
1	128	150
2	64-128	300-500
3	42-56	300-500
4	56-64	200-300
5	64-128	100-200
6	90-128	200

Next the results for a delivery environment characterised by a bandwidth in the range of 42 kbps and 56 kbps and RTT in the range of 300-500 msec (Connection Type 3) are presented. This scenario is common for users with a modem connection. Figure 4 illustrates a comparison between the two cases that involve the usage or not of the QoE-based adaptation mechanism for delivering the randomly selected ten Web pages. Taking into account the suggested content-based adaptations different percentages of reduction in the Web page size were applied. For this case, only image compression was considered and no image elimination was applied. One can observe that the download time per page did not exceed 14 sec. This value is below the 15 secs limit for acceptable download time for a user aware of low bit-