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유무선 인터넷 환경에서 TCP와 SCTP의 성능 비교*

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<국문초록>

HTTP는 월드 와이드 웹에서 가장 널리 사용되는 프로토콜의 하나로 신뢰성을 제공하기 위해 전송 계층 프로토콜로 TCP를 사용한다. HTTP는 개별적인 파일 요청에 대해 분리된 TCP 연결을 사용하기 때문에 파일 수신에 있어서 불필요한 오버헤드인 헤드-오브-라인 (head-of-line) 블로킹을 유발시킨다. 웹 응용은 일반적으로 전송되는 크기가 작기 때문에 무선 환경에서는 TCP로 인한 핸드오버의 지연이 증가한다. 이에 비해 최근에 제안된 SCTP(stream control transmission protocol)는 멀티-스트리밍과 멀티-호밍과 같은 매력적인 기능을 갖고 있다. SCTP의 이러한 기능들은 TCP의 헤드-오브-라인 블로킹을 제거하고, 무선 환경에서 TCP의 핸드오버 지연을 줄이는 것으로 기대되고 있다. 평균 응답 시간은 대부분의 웹 응용에 있어서 중요한 측정 요소이다. 본 논문에서는 NS-2 시뮬레이터를 이용하여 유무선 인터넷 환경에서 SCTP와 TCP의 평균 응답 시간을 비교하였다. 이를 위해, 유선 환경에서는 패킷 손실률, 대역폭, RTT(Round Trip Time) 및 웹 객체의 개수의 변화에 따른 평균 응답 시간이 비교되었고, 무선 환경에서는 이동속도 및 반경의 크기에 따른 평균 응답 시간과 패킷 손실률이 비교되었다. 시뮬레이션 결과는 SCTP가 TCP의 평균 응답 시간을 감소시키는 것으로 나타났다.

주제어 : 유무선 인터넷, SCTP, 응답시간, 시뮬레이션

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Ⅰ. Introduction

HTTP (hypertext transfer protocol) is the de facto standard for transferring World Wide Web documents, although it is designed to be extensible to almost any document format. HTTP/1.1 (Fielding et al., 1997) deploys persistent connections to retrieve all the data items from the same server. This reduces the insignificant overhead experienced by the user. The HTTP/1.1 was developed as a means for reducing both document transfer latency and web traffic.

There is a mismatch between the functionality and requirement of TCP (transmission control protocol) and HTTP respectively. The major drawbacks are the HOL (head-of-line) blocking with a single TCP connection and vulnerability to denial of service SYN attack. TCP is a byte-stream-oriented protocol and there is no message boundary preserved. TCP can only provide strict-ordering and reliable data delivery and many applications need reliable message delivery, but not strict byte sequence maintenance.

Strict-ordering of TCP can also lead to unnecessary head-of-line blocking issue, where the loss at head of line delays delivery of subsequent data or block other received data. Hence, when TCP is used for web transport, a lost web object may block delivery of other successfully received independent web objects. This problem is due to the fact that TCP cannot logically separate independent application level objects in its transport and delivery mechanisms.

SCTP (stream control transmission protocol) was standardized for carrying PSTN signaling messages over an IP network (Stewart et al., 2000). The SCTP's new feature includes multi-streaming and multi-homing (Fu & Atiquzzaman, 2004). To alleviate the HOL blocking problem SCTP uses the multi-steaming feature to transfer the web objects. To protect an end host from such SYN attacks, SCTP uses a four-way handshake with a cookie mechanism during association establishment. The four-way handshake does not increase the association establishment latency, since data transfer can begin in the third leg.

A number of studies have analyzed the evaluation and performance of HTTP. Jungmaier et al. (2000) compared the delivery delay for TCP and SCTP packets operating over a communication channel. They have shown that in TCP networks, multiple losses during a short period can cause significant fluctuation in the delivery delay. They have also proposed a modified SCTP retransmission algorithm, which can significantly improve the performance of SCTP in long delay networks. The web latency is addressed in (Venkata et al., 1995; Fu et al., 2005; Lee & Atiquzzaman, 2005). The performance comparison of HTTP/1.0 and HTTP/1.1 can be found in (Braford & Crovella, 1999). Rajamani et al. (2002) also studied the performance of SCTP and TCP for the web traffic. They have shown that SCTP can help to improve the throughput comparing to TCP when a client tries to download multiple files through a web server using HTTP protocol. The most important performance measure in a web environment is the mean response time between HTTP requests and replies. The previous papers did not consider the mean response time in wired and wireless Internet environment.

In this paper, we have compared the mean response time of HTTP over SCTP and HTTP over TCP using NS-2 simulator (2008) in wired and wireless Internet environment. The paper is organized as follows. Section 2 describes the features of transport protocols supporting web application. Section 3 describes performance evaluation that shows the results and protocol performance. Finally section 4 concludes the paper.

Ⅱ. Protocols supporting web application

Typical TCP and UDP do not completely match the requirements to carry signaling across Internet. UDP is connectionless and messaged-based and it can only provide an unreliable datagram service. The TCP, on the other hand, provides error control and flow control and reliable transport of data information; however it has other drawbacks that decrease it suitability to transfer of signaling information.

SCTP is a reliable datagram transfer protocol operating on the top of an unreliable routed packet network such as IP. The SCTP provides applications with enhanced performance, reliability, and control functions. This protocol is essential where detection of connection failure and associated monitoring is enforced. SCTP is designed to overcome some of the constraints of TCP and UDP to provide a reliable end-to-end message transportation server over IP-based networks. SCTP gains advantage over TCP and UDP by the virtue of its unique features such as path selection and monitoring, validation and acknowledgement mechanism and multi-streaming.

1. HTTP over TCP

Consider the simple case of a web browser displaying a web page with embedded objects. Using HTTP/1.1 that supports persistent and pipelined connections, the browser opens a new transport connection to the server, and sends an HTTP GET request with the desired Uniform Resource Identifier (URI). The request may consist of a specific command, a message containing request parameters, information about the client and may contain URI's of embedded objects. The server returns an HTTP response with the page contents. The response includes status information, a success/error code, and a message containing information about the server and information about the response itself. As responses arrive from the server, the browser displays the webpage with its embedded objects. In general, objects embedded within a web page are independent of each other. That is, requesting and displaying each object in the page does not depend on the reception of other embedded objects. However, the number of connection for TCP is one, which leads to HOL blocking problem that causes performance degradation.

To alleviate HOL blocking, web browsers usually open multiple TCP connections to the same web server. Using multiple TCP connections for transferring a single application's data introduces many negative consequences for both the application and the network. It may cause the increased load on web server. Under high loads, some web servers may choose to drop incoming TCP connection requests due to lack of available memory resources. The other drawback is increased connection establishment latency. Each TCP connection goes through a three-way handshake for connection establishment before data transfer is possible. This handshake wastes one round trip for every connection opened to the same web server. Increasing the number of connections increases the chances of losses during connection establishment, thereby increasing the overall average transfer time.

These drawbacks can be eliminated by the inclusion of SCTP as the transport protocol for web traffic.

2. HTTP over SCTP

The SCTP distinguishes different streams of messages within one SCTP association. This enables a delivery scheme where only the sequence of messages needs to be maintained per stream (partial in-sequence delivery). The message loss in a particular stream will only hinder delivery of that stream. Therefore, other streams within an association are not affected. By using unordered messages and multi-streaming, SCTP eliminates the head-of-the-line blocking problem. When SCTP is used for web page retrieval; it allows multiple streams in an association and independent streaming delivery of web objects. This avoids the HOL blocking experienced when TCP is deployed for web object retrieval. In contrast to the three-way handshake that occurs in TCP, SCTP uses a four-way handshake and verification tag to initiate an association.

The SCTP operates like TCP (using window-based flow control) with the additional features necessary to transport signaling information. Detection of loss and duplication of data chunks is enabled by numbering all data chunks in the sender with the so-called Transport Sequence Number (TSN). The acknowledgements sent from the receiver to the sender are based on these sequence numbers. Retransmissions are timer-controlled. The timer duration is derived from continuous measurements of the round trip delay. Whenever such a retransmission timer expires, all non-acknowledged data chunks are retransmitted and the timer is started again doubling its initial duration (like the TCP). Whenever the sender receives four consecutive SACKS reporting the same data chunk missing, this data chunk is immediately retransmitted (fast retransmit). Data that is discarded, reordered, duplicated or corrupted can be detected and fast retransmitting and fast recovery for damaged data can be issued. This congestion control mechanism improves the performance of SCTP in wireless environment. The above stated features show that SCTP can be best suited for HTTP application with improved performance.

3. Mean response time

Mean response time is defined as the time elapses between the initial request from the client and the response from the server. In the evaluation of web performance, mean response time is the most widely used measure. In TCP connection, the client sends a request to the server. The server parses the request and sends the HTML file with embedded objects. Then the client sends a request for the embedded objects using persistent and pipelining connections. The SCTP association supports independent delivery of web objects in an association.

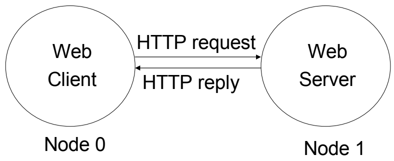
Ⅲ. Performance evaluation

We have performed simulation using NS-2 simulator and compared the performance of TCP and SCTP in wired and wireless environment. The version of NS-2 used is 2.29.

1. Wired environment

The topology for wired simulation is shown in Figure 1. In the topology node 0 represents web client and node 1 represents web server. In simulation model the client initiates sessions with the web server. The results were obtained from the trace file generated in the siulation.

We have used TCP and SCTP as the transport protocol for the HTTP traffic in ns-2 simulation. The parameters such as bandwidth, round trip time, maximum segment size, number of objects and packet loss rate etc are given in <Table 1>.



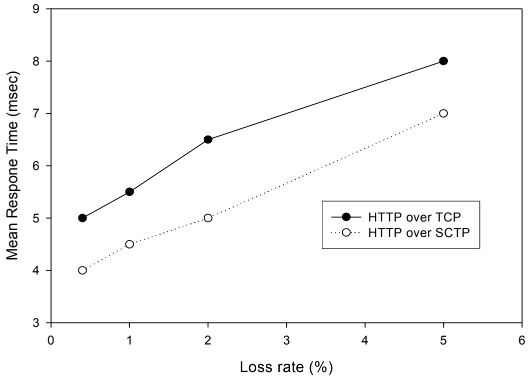
[Figure 1] Topology for wired simulation

<Table 1> Simulation parameters used in wired environment

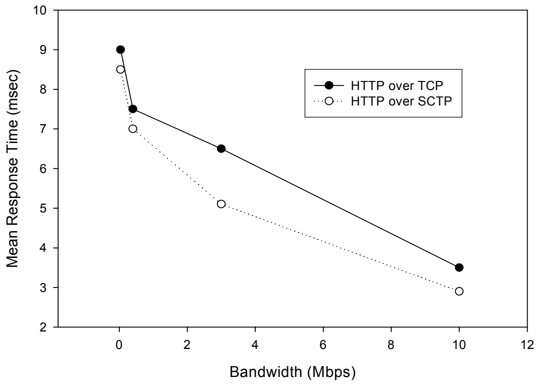
Test parameters	Object size (KB)	Bandwidth (Mbps)	Number of Objects	RTT (ms)
Object size	13.5	0.04	5	-
Number of objects	13.5	0.04, 0.4, 3, 10	5	-
Bandwidth	13.5	0.04	5	55, 80, 256, 1000
RTT	13.5	0.04	3, 5, 10, 20	-

The plots of packet loss rate vs. mean response time for HTTP over TCP as well as HTTP over SCTP is presented in Figure 2. The packet loss rate was varied from 0.4 % to 5 % and the mean response time was observed. The bandwidth, RTT, the maximum segment size and object size are 40 Mbps, 256 ms, 536 B, 13.5 KB respectively. It can be seen from the Figure 2 that for both the HTTP over TCP as well as HTTP over SCTP, the mean response time increases as the packet loss rate increases. The increase in packet loss rate tends to HOL blocking problem when TCP is used for web transaction and this in turn increases the response time. This can be eliminated by SCTP's multi-streaming feature, which allows multiple streams in an association.

The effect of bandwidth on mean response time for both the protocol is presented in Figure 3. The figure shows the mean response time is inversely proportional to the bandwidth. As the bandwidth increases, it reduces the transfer time, as well as the mean response time. If the bandwidth increases the packet loss rate will be reduced. This tends to reduce the transfer time when fetching the web objects.

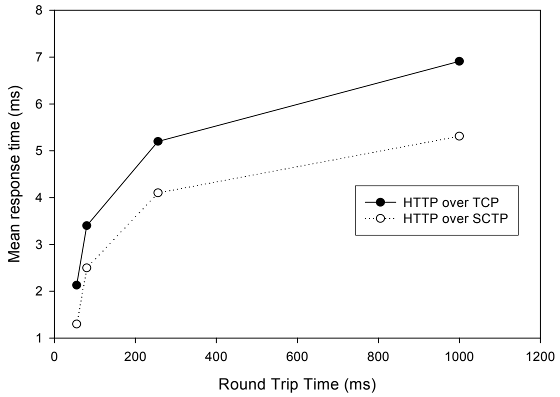


[Figure 2] Mean response time for packet loss variation



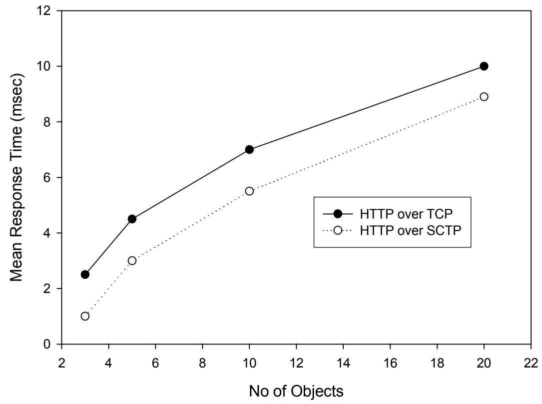
[Figure 3] The effect of bandwidth on mean response time

Figure 4 shows the mean response time increases as the RTT value increases. SCTP has better performance because of its multi-streaming feature. The RTT is varied from 55 ms to 1000 ms and the mean response time is observed. Since TCP has no multi-streaming feature, the web objects require extra round trip time. This increases the mean response time of TCP than SCTP.



[Figure 4] Mean response time for RTT

Figure 5 shows the increase in mean response time as the number of object increases. If the number of objects are more, if any of the object fails the remaining objects are queued up until the object is retrieved. This causes the increase in transfer time. SCTP has better performance compared to TCP because of its multi-streaming feature.



[Figure 5] Mean response time for number of objects

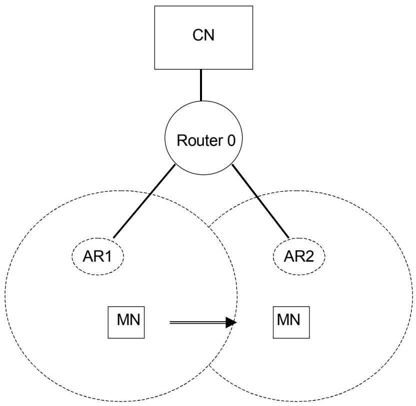
2. Wireless environment

The wireless simulation topology is shown in Figure 6. The web server (CN: correspondent node) is located in the wired network and a web client(MN: mobile node) is moving between two wireless stations. In Figure 6, AR1 and AR2 represent access routers which perform both the access pointer function and the router function. CN is located in the Internet and connected to Router 0. The arrowhead shows the mobile node movement from AR 1 to AR 2.

The wired link between CN and Router 0 has the bandwidth of 2 Mbps and the delay of 5 ms. The link between Router 0 and AR1 and AR2 have the bandwidth and delay of 2 Mbps, 2 ms respectively.

The performance comparison of TCP and SCTP is given in Table 2. In order to view the impact of moving speed on mean response time, the speed of the MN is varied from 5 m/s to 20 m/s.

The other parameters we have used in the simulation are object size = 13.5 KB, RTT = 256 ms, maximum segment size = 536 B, packet loss rate = 0.4 %. The overlapped region size is varied from 1 m to 15 m and the effect on mean response time and packet loss is observed.



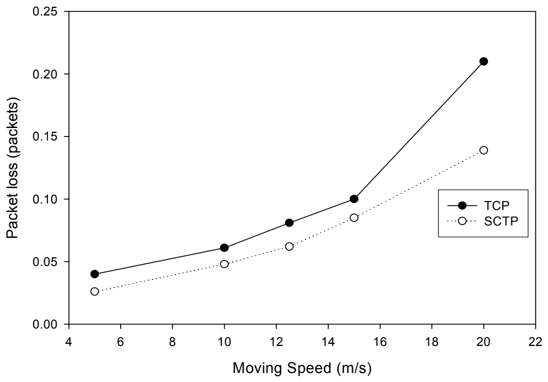
[Figure 6] Topology for wireless simulation

<Table 2> The performance comparison of TCP and SCTP in wireless environment

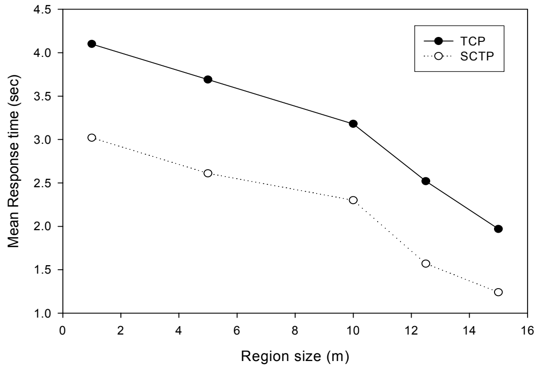
Performance measure	Impact factors		TCP (mean)	SCTP (mean)
	Factors	Values		
Mean Response Time (sec)	moving speed (m/s)	5, 10, 12.5, 20	2.02	1.61
	region size (m)	1, 5, 10, 12.5, 15	2.97	2.10
Packet loss (packets)	moving speed (m/s)	5, 10, 12.5, 20	0.09	0.06
	region size (m)	1, 5, 10, 12.5, 15	0.12	0.08

The plots of moving speed vs. mean response time is shown in Figure 7. It can be seen that the mean response time increases as the moving speed increases. The packet loss increases as the moving speed increases and hence the increase in mean response time.

The region size of the base station is varied to view the impact on mean response time as well as the packet loss. Figure 8 shows the result of mean response time for different values of region size. In both the cases SCTP has improved performance than TCP. As the region size is increases, both the packet loss and the mean response time decrease.



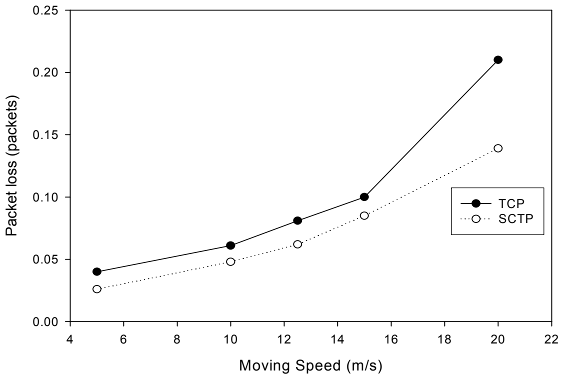
[Figure 7] Effect of moving speed of MN on mean response time



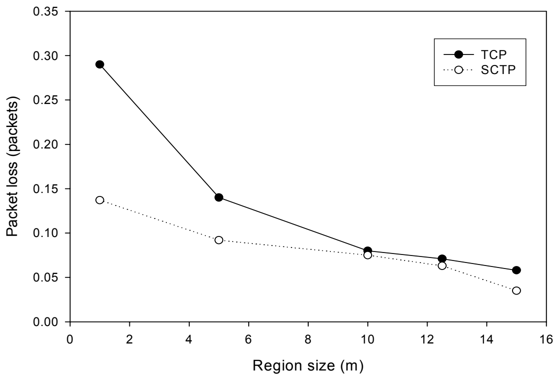
[Figure 8] Effect of region size on mean response time

Figure 9 and Figure 10 show the effect of moving speed on packet loss and the results obtained for various region size vs. packet loss, respectively. From the figures it can be seen that SCTP has better performance than TCP.

These results imply that multi-streaming and multi-homing features of SCTP provide improved performance in wired and wireless networks than TCP.



[Figure 9] Moving speed vs. packet loss



[Figure 10] Region vs. packet loss

Ⅳ. Conclusions

In this paper we have analyzed and compared the performance of SCTP and TCP as the transport layer protocol for the web traffic. SCTP has attractive features such as multi-streaming and multi-homing, makes it best suited for web application. To compare the performance we have carried out experiments using NS-2 Simulator. Our results show that the mean response time of SCTP can be reduced remarkably as that of TCP. The future work includes the analytical model for performance analysis of SCTP based web traffic.

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<Abstract>

Performance Comparison of TCP and SCTP in Wired and Wireless Internet Environment*

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HTTP is one of the most widely used protocols of the WWW. Currently it uses TCP as the transport layer protocol to provide reliability. The HTTP uses separate TCP connection for each file request and adds unnecessary head-of-line blocking overhead for the file retrieval. The web application is short sized and affected by the increased handover latency of TCP in wireless environment. SCTP has attractive features such as multi-streaming and multi-homing. SCTP's multi-streaming and multi-homing avoid head-of-line blocking problem of TCP and reduce handover latency of TCP in wired and wireless environment. Mean response time is the important measure in most web application. In this paper, we present the comparison of mean response time between HTTP over SCTP with that of HTTP over TCP in wired and wireless environments using NS-2 simulator. We measured mean response time for varying packet loss rate, bandwidth, RTT, and the number of web objects in wired environment and mean response time and packet loss rate for varying moving speed and region size in wireless environment. Our experimental result shows that SCTP reduces the mean response time of TCP based web traffic.

key words : wired and wireless Internet, SCTP, response time, simulation

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