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SCTP Protocol Reviews and Performance in Ad-Hoc Multi-Homed Networks

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Abstract **: Ad hoc networks are mobile nodes without infrastructure, where each node communicates over wireless channels, moves freely and may join and leave the network at any time. This feature may cause problems for higher layers when it unexpectedly exits lower layer in the protocol stack. SCTP is a message oriented and reliable transport layer protocol with some interesting features for applications development in ad hoc networks. Among the others, multi streaming and multi homing is one of the most interesting capabilities, that allows to increase the throughput, because it reduces the head-of-line (HOL) blocking effects. In this paper we evaluate the SCTP protocol behavior in order to show the advantages of multi streaming and multi homing in ad hoc scenarios. Ad hoc networks consist of a wireless and highly dynamic environment, in which links break frequently and errors affect communication channels.**

Keywords**: Mobile Ad-Hoc Network, SCTP, Multi-Streaming, Multi-Homing, HOL**

I. INTRODUCTION

In the last few years, ad hoc networks have emerged as a promising approach for communication in mobile environments. However, ad hoc networks are characterized by unique properties and challenging problems that limit the utilization of traditional networking techniques and protocols in this context. Wireless links are highly error prone and they can break frequently because of node mobility, interference and channel fading. It implies, for example, that at the network routing paths between source and sink frequently change. it is very hard to maintain an end-to-end routing, cause of dynamic topology of the system. In this paper we consider the problem of maintaining reliable end-to-end communication in an ad hoc network. SCTP are reliable transport protocols. It is desirable to use such protocols also in ad hoc networks in order to provide seamless portability of well-know applications, like message transfer, browsing and multimedia streaming. These protocols have been designed for communicating in fixed networks, so they do not perfectly fit to wireless environments. For example, SCTP interpret message loss as congestion and they invoke congestion control mechanisms, which limit messages transmission and, consequently, decrease the offered throughput. SCTP uses multi-homing to control congestion in networks. Multi-homing is a concept where a node uses the more than one path for communication, one is primary path and another is alternate path. In ad hoc networks several causes may determine lost of messages, because communication links are wireless, data delivery is based on multi-hop path and nodes move freely and unpredictably. Since the probability of losing messages is high, the congestion control based on expiration-timer for retransmission is not much suitable in this kind of environment and other mechanisms have to be adopted. SCTP provides a good alternative to TCP, the most common transport protocols that may better satisfy the requirements of ad hoc networks. Unlike TCP, SCTP is a message-based connection-oriented transport protocol that provides delivery of user messages within multiple and independent streams (i.e., partially-ordered data delivery). We believe that SCTP is an effective solution for the reliable communications in ad hoc networks because it reduces effects caused by errors in wireless channels and due to node mobility. Also it takes advantage from the under layer routing protocol that can provide multiple-path for data delivery. This paper aims to show how this ability is particularly helpful in increasing good put and reducing overhead in high loss environments, like ad hoc networks. To underline the usability of SCTP, we point out that it is a standard defined by IETF. It allows already to design and develop ad hoc applications with great flexibility, because it is implemented for Linux/Unix kernel and the most common simulation tools for ad hoc networks (like NS2 and Qualnet) provide the SCTP module. It supports both IPv4 and IPv6 addressing for maximum interoperability. All these considerations led us to investigate SCTP behavior in the context of ad hoc networks. We have performed an in-depth study of the SCTP protocol and we have evaluated the effect of dynamic topology and unreliable links on SCTP performance.

II. SCTP MULTISTREAMING & MULTIHOMING

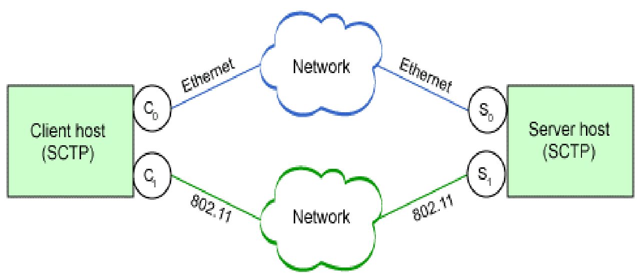


Fig. 1(a) SCTP multi-homing

Stream Control Transmission Protocol (SCTP) [RFC2960] is an end-to-end transport protocol that provides services heretofore unavailable from either of the workhorse transport protocols that have supported the Internet for more than twenty years: reliable, connection-oriented TCP [RFC793], or unreliable, connectionless UDP [RFC768]. *Multi-homing* is an essential property of SCTP is its support of multi-homed nodes, i.e. nodes which can be reached under several IP addresses. If we allow SCTP nodes to support more than one IP address, during network failure data can be rerouted to alternative destination IP addresses. This makes the nodes more tolerant against physical network failures and other problems of that kind.

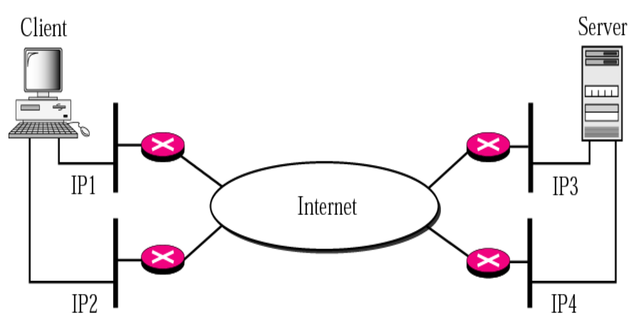


Fig. 1(b) Multi-homing

Multi-streaming is an effective way to limit Head-of-Line Blocking. The benefit in having multiple independent data streams is if a packet is lost in one stream, while that stream blocks to wait for the retransmission the remaining unaffected streams can continue to send data. In TCP if a packet is lost, the connection effectively grinds to a halt while it waits for the retransmission to be sent [2]. This phenomenon where packets are blocked by a packet in front which has been lost is known as Head-of-Line blocking and can be illustrated thus:

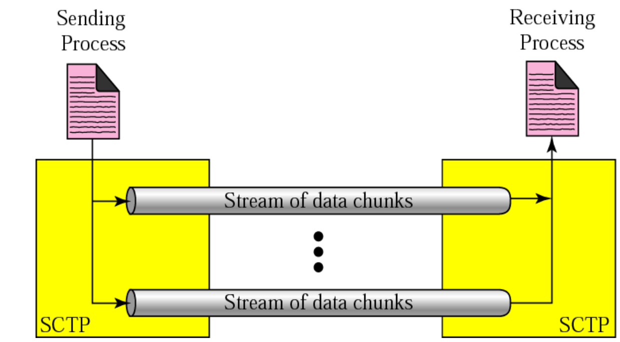


Fig. 2(a) SCTP multi-streaming

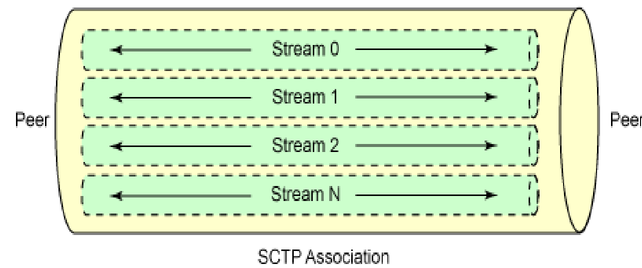


Fig. 2(b) SCTP Association (multi-streaming)

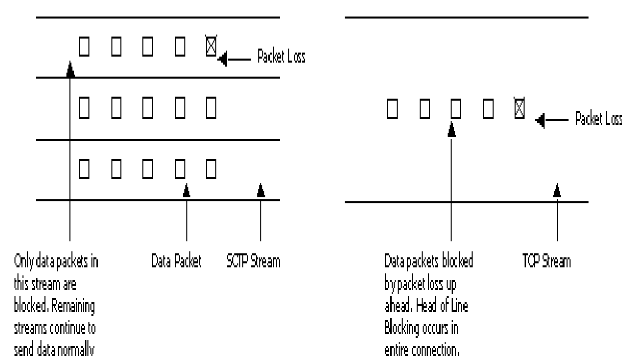


Fig. 3 TCP Connection

An SCTP association is equivalent to a TCP connection; they both represent an end-to-end relationship between two transmitting nodes. Multi-streaming can be achieved in TCP, however it involves opening multiple TCP connections which each act as a stream to send data. This differs from multi-streaming in SCTP where all the streams reside in a single association. Opening multiple TCP connections is TCP-unfriendly, which means that a pair of communicating nodes will obtain a larger proportion of the available channel bandwidth. Thus, SCTP is more TCP-friendly in this regard. Although multi-homing and multi-streaming may be where SCTP and TCP differ most, the two protocols exhibit other differences, which are also important to discuss.

III. Related Work

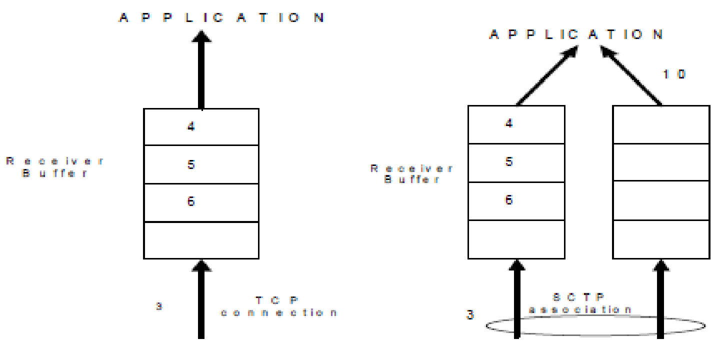
Some researchers have paid attention to how SCTP supports ad hoc scenarios. In [6] a brief comparison between the performances of TCP vs. SCTP within ad hoc networks was presented. The analysis was performed through simulations with reference to nodes mobility. For analysis they used the simulator NS2, while the scenario used was constituted by 46 mobile nodes inside an area of 1000x300 m2 with CBR traffic. The authors shown the faster decreasing of the SCTP performances, in term of goodput, in comparison with TCP, they infact, from their point of view, assess that the TCP outperfoms SCTP. Besides increasing the mobility, the number of retransmission go up, and the TCP introduce better performances. However the provided analysis is poor and the dissertation is too short to explain well the issue. In [1] the authors have evaluated performances of SCTP with two different routing protocols: AODV and DSR. For the analysis was employed the simulator NS2. The scenario was dynamic, the nodes had a maximum speed of 20 m/s inside an area of 600x600 m2, while simulation time of was of 200 s for each proof. They assert that, independently from the routing protocol, the percentage of delivered messages is sensitively less in TCP respect to SCTP. This one succeeds having a elevated throughput. The authors did not consider proactive routing protocols. In [15] SCTP was investigated with reference to the effect of congestion on the throughput. The simulative study was performed on static scenarios constituted by four hosts along a straight line (*string topology*). Under these conditions the authors analyzed the throughput varying the dimension of the receiver's window and also varying the number of hops. They have shown that the throughput decreases with the increase of the number of hops and that a larger receiver's window does not guarantee an increase in the overall throughput. Then, they have proposed a modified SCTP to improve the throughput. The simulation scenario is too much simple, and the authors do not assess the behavior of ad hoc environment.

IV. SCTP & Ad-hoc Network

The Stream Control Transmission Protocol (SCTP) emerged from the need for telecommunications companies to manage SS7 applications and services over an IP infrastructure. It was developed to overcome the limitations of TCP to accomplish signaling transport, but it was soon noticed that SCTP is useful in a wider range of applications, instead of just the signaling transport area [11]. SCTP is reliable, connection and message oriented (i.e. it preserves message boundaries) and it offers a partiallyordered service. Such transport protocol is ideal for applications that need flexible control over the ordering of individual elements, like multimedia applications. Application data can be divided in independent Application Data Units (ADUs) and SCTP processed ADUs in different data streams (multistreaming approach). Each stream is kind of a sub-flow within the overall data flow, and the delivery of a sub-flow is independent from the others. SCTP multiplexes several data streams into one SCTP association. In SCTP, *association* is the name for the communication relationship between end points, and is similar to *connection* in TCP. Within streams, SCTP uses stream sequence numbers (SSNs) to preserve
the data order and reliability for each data chunk. Between streams, however, no data order is preserved.

Multistreaming reduces the *head-of-line (HOL)* blocking effect resulting from the TCP strict by-order delivery policy, in which successfully transmitted segments must wait in the receivers queue until a TCP sending end point retransmits any previously lost segments. This blockage delays delivery of data to the receiving application until the retransmitted segments are received, which is unnecessary and sometimes unacceptable in signaling and some multimedia applications. The issue of the HOL is shown in Figure 4(a). At the receiver station, messages are stored in a buffer before being delivered to the application layer. If segment 3 is lost, the HOL blocking receiver must wait that it is retransmitted before being able to deliver all the messages in the buffer (segments 4, 5 and 6). Also, if the buffer is full, the sender cannot transmit more data (Figure 4(a)). It means that the application does not receive data for the meantime and hence it suffers from delay. In (Figure 4(b) is shown the receiver buffer in presence of multi-streams. If segment 3 belonging to the first stream is lost, the application layer will not receive segments 4, 5 and 6 stored in the buffer, but it will receive messages of others streams (for example message 10). In this way the rate of message delivery is increased in comparison with the previous case. Advantages deriving by the usage of multiple and independent streams are greater in ad hoc networks. Ad hoc networks are multihop wireless networks without a pre-installed infrastructure in which nodes communicate in a distributed way. Due to node mobility, changes into the routing path can occur. During path restoration, some messages can be lost. In a TCP connection it means interruption of delivery, whereas in a SCTP association only a stream suffers from delay. While SCTP manages ordering and message delivery on a per-stream basis, it manages congestion control on a per-destination basis. In other words, an SCTP sending end point maintains a separate congestion window for each destination.

Similarly to TCP, a congestion window (CWND) constrains the amount of data that an SCTP sender can send, thus controlling the sending rate to avoid congestion in the network. Even in ad hoc networks it assures a good reaction if congestion occurs on some communication channels. Since in ad hoc networks there are not collectors for packet delivery, several paths can be drawn between whichever couple (source, destination). It has been proved that multi-path routing strategies improve load balancing and packet delivery ratio. It justifies the increasing interest of researchers toward new multi-path routing protocols development [12][7][8]. SCTP multihoming features allow multi-homed machines to have multiple IP addresses. If connectivity is lost on the primary IP address being used for the association, the association will pass to an alternate IP address. Due to the multi-homing function of



(a) HOL blocking with TCP

(b) Reduction of HOL blocking with SCTP

Fig. 4 HOL blocking

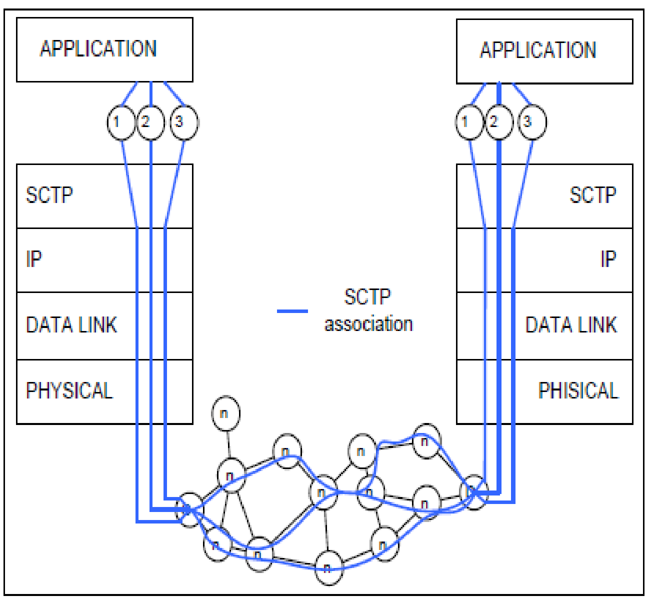


Fig. 5 SCTP in Ad-hoc network

SCTP, one transport connection may contain multiple path in general. So SCTP supports also ad hoc multi-path connections. Streams are independent on each other and they can be routed along different paths, in order to prevent congestion in the network and to satisfy QoS requirements. Furthermore, if these paths are disjoint, the losses experienced by the sub-streams would be relatively independent. On the contrary, TCP is designed only for single-path connection and it suffers dramatically on multi-path routing protocols [9]. In Figure 1 are depicted multi-streaming and multi-homing functionalities of SCTP in ad hoc networks.

V. SCTP PERFORMANCES

In this Section we provide a detailed analysis of the experimental results performed with the NS2 simulator in order to show how ad hoc networks benefits from the multistreaming functionality implemented in SCTP. To achieve such purpose, we present a comparison of SCTP behavior versus TCP. It is needed to underline that the comparison is done with two protocols in a standard version without any optimization.

A. Error Rate

As previously explained, the error rate summarizes all the issues that may cause faults in wireless links. At this stage we prefer to include the mobility effect inside a wide error. The errors appear in each link of whole Ad Hoc Network. We want to explore how such errors affect the SCTP performances. At this stage of our analysis in simulations we have set to 5KB the receiver buffer and to 5 the number of streams managed by SCTP, in order to show the impact of multistreaming on ad hoc networks. In the following subsections we will provide a characterization of SCTP in terms of number of streams and buffer size. We have performed simulations with 50 nodes and FTP traffic. To analyze how the load of traffic in the network affects the system, we have considered three sets of simulations that are characterized by different traffic sources. At first we have set just one FTP connection among the nodes in the network. In the following set of simulations we have considered two FTP connections and finally three FTP connections among nodes. The error rate assumes values in the range [1%□10%]. As can be observed, SCTP delivers more messages in comparison to TCP. High error rate on link channels emphasizes the Head Of Line blocking problem. In the TCP case, whenever a segment is lost, the receiver cannot send data to the application until the segment is received after a retransmission . Also, if the receiver buffer is full, the sender cannot anymore send data. In the SCTP case, data are subdivided in independent streams and data at the receiver reach the application layer, except for streams affected by loss. The more are the number of streams the lower is the impact of messages loss. This is the reason why SCTP improves the goodput in comparison with a single flow. Very similar results have been observed in presence of higher data traffic (two and three FTP connections), but we do not reproduce them for the paper length constrains. To Goodput of TCP and SCTP with the error rate, evaluate how much the SCTP outperform the TCP, we have defined the *gain* as the ratio between the number of SCTP messages and that of TCP messages received, assuming the same simulation scenario, that is under the same conditions. The *gain*, expressed as percentage, is plotted as a function of the error rate. Figure 7 shows the results of simulation trials with one, two and three FTP connections and, as can be observed, there is a common trend such that the higher is the error rate, the greater is the improvement of SCTP with respect to TCP. Thus we can assert that SCTP is less sensitive to errors in wireless links and that adopting the SCTP at the transport level when channels are affected by errors is more convenient than using the TCP.

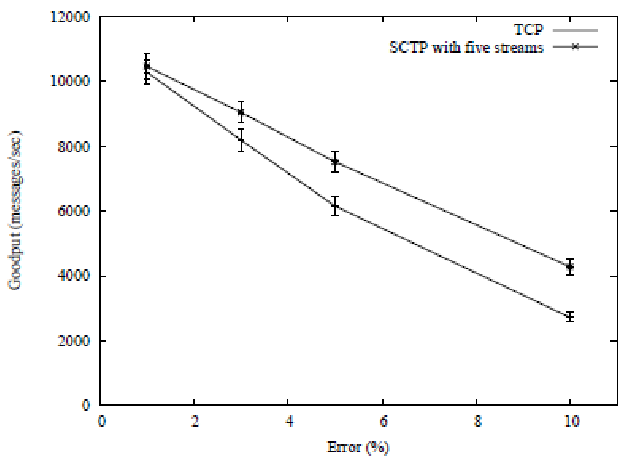
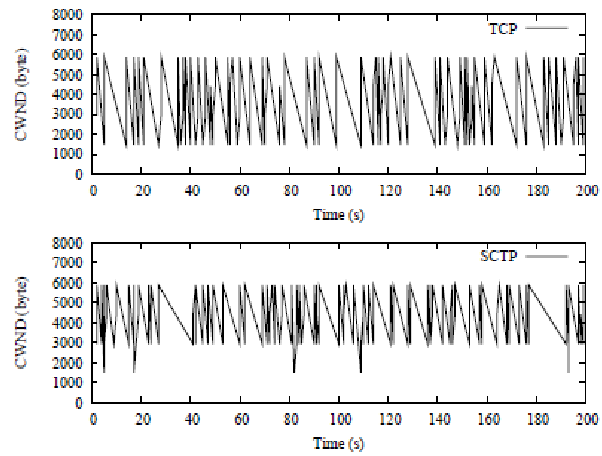


Fig. 6 Performance analysis of SCTP & TCP

B. Congestion Window

To show the effects of the Head of Line blocking problem and to understand how it may degrade the overall throughput, we have observed the Congestion Window (CWDN) behavior on the sending end point in simulations with one FTP connection, assuming both SCTP and TCP. SCTP and TCP use a similar end-to-end congestion control mechanism based on the CWND that controls the maximum number of outstanding bytes (i.e. bytes that may be sent before they are acknowledged). Congestion control has two modes, slow-start and congestion-avoidance. In slow-start, the CWND is increased faster, until it exceeds a certain boundary (called Congestion Windows comparison when the receiver buffer size is 10 Kbyte slow-start-threshold *ssthresh*). Then the mode changes in congestion-avoidance. When a message is lost, the *ssthresh* is cut down drastically, and the CWND is reset. The Fast Retransmit mechanism is an additional feature derived from the TCP that limits the deterioration of the throughput in presence of messages lost. When an outof- order segment arrives, the receiver sends a Selective Acknowledgment (SACK) that specifies the gap in the sequence space. After the arrival of 4 consecutive SACKs related to the same segment, the sender performs a retransmission of the missing segment, without waiting that the *Retransmission TimeOut* (RTO) expires. Events that trigger the retransmission of messages (timeouts or fast retransmission) cause the cut of the CWND size. In particular, if the RTO expires, the CWND is set to 1MTU. If the Fast Retransmit runs, the CWND is halved.

In our simulations MTU is set to 1500 bytes. Figure 7 shows the congestion windows of TCP and SCTP in a time range of



0-200 sec, assuming an error rate in the wireless link of 0,5%. We have considered in simulations 0,5% as error rate in

Fig. 7 Congestion windows comparison

wireless links. The curves show that on average, the CWND size is higher in the SCTP than in the TCP, since in the TCP case, when messages are lost, the CWND is always cut to 1MTU (1500 bytes); whereas in the SCTP case, most of the times the CWND is reduced to 2MTU (3000 bytes). The reason of such behavior is that in a TCP connection there is a frequent expiration of the RTO, while in the SCTP usually a Fast Retransmit occurs before that RTO expires. The Fast Retransmit is bound to the SACK message sent by the receiver when new messages are stored in the buffer. So, even the fast retransmit depends on the ability of the receiver to process a higher quantity of segments in the receiver buffer. If the buffer is full, data transmission is stuck and the Fast Retransmit does not work.

C. Number of flows

The results we have described until now clearly show how multistreaming in SCTP improves data delivery in ad hoc networks. In this subsection we estimate the optimal number of SCTP streams for wireless links characterized by 5% of error rate. We intend to identify the minimum number of streams *n* that guarantees the best performances in terms of goodput and overhead. be observed, if we increase *n* over 5 streams, SCTP performances do not improve any further: a constant value is reached, regardless of the number of active streams. If too many streams are active at a given time, errors affect several streams at the same time and messages cannot be delivered to the application layer, even if they are stored in different queues. On the other side, the higher is *n*, the higher should be the buffer size and hence the memory usage, because each stream needs independent queues at the receiver. Since ad hoc The best number of flows, in terms of goodput devices are characterized by low resource supply, it is important to dimension the communication system with the utmost care. These considerations explain why wehave performed our above study assuming a maximum number of 5 concurrent SCTP streams.

VI. Conclusion

In this paper we have evaluated the SCTP behavior in order to show the advantages of multistreaming in ad hoc networks. Ad hoc networks are highly error prone because of node mobility and interference and channel fading on wireless links. This is why we have assumed a system characterized by high error rate in the wireless communication links. At first we have discussed

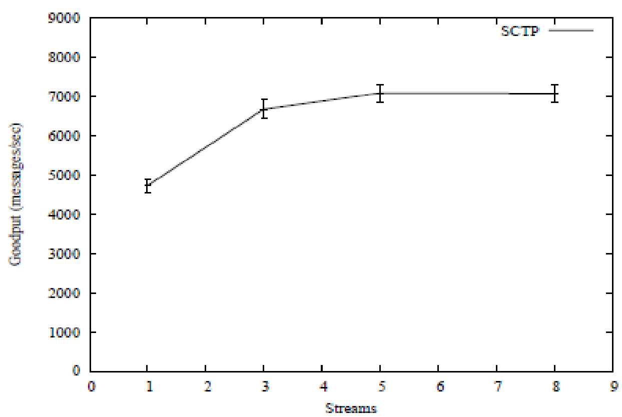


Fig. 8 The best number of flows, in terms of goodput

the error model that summarizes the possible causes of message lost in the network and we have selected the routing protocol that affects the least the SCTP performance. Then we have presented our results comparing the SCTP against the TCP, assuming different scenarios. The main result we have achieved has been to prove that multistreaming increases goodput and reduces overhead if many errors occur during the communication because it limits the HOL blocking problem. Furthermore, the SCTP outperforms TCP especially if small buffers at the receiver end point are used. Since wireless devices in ad hoc networks are generally characterized by limited resources and the size of the receiving buffer is directly proportional to the dimension of the device and to its power consumption, this result is very interesting. As consequence of the results we have shown in this paper, we can assert that at the transport layer the SCTP well fits to provide reliable communications over ad hoc networks and it offers a good starting point for developing applications with strict constrains on data delivery rate (for example multimedia applications) for such kind of environment.

Refrences

[1] Antonios Argyriou and Vijay K. Madisetti. Performance evaluation and optimization of sctp in wireless ad-hoc networks. In *LCN*, pages 317–318, 2003.

[2] M. Atiquzzaman and W. Ivancic. Evaluation of sctp multistreaming over satellite links. In *12th International Conference on Computer Communications and Networks*, Oct 20-22 2003, Dallas TX.

[3] K. Fall and K. Varadhan. *ns Notes and Documentation. The VINT Project, UC Berkeley, LBL, USC/ISI, and Xerox PARC*. Available http://www-mash.cs.erkeley.EDU/ns/, 1999.

[4] P. Mahonen G. Xylomenos, G. C. Polyzos and M. Saaranen. Tcp performance issues over wireless links. In *Mobicom 2003*, 2003.

[5] D. B. Johnson, D. A. Maltz, Y-C. Hu, and J. C. Jetcheva. *The Dynamic Source Routing Protocol for Mobile Ah Hoc Networks*, 2 March 2001.

[6] Ashwini Kumar, Lillykutty Jacob, and Akkihebbal L. Ananda. Sctp vs tcp : Performance comparison in manets. In *LCN*, pages 431–432, 2004.

[7] S. Lee and M. Gerla. Split multipath routing with maximally disjoint paths in ad hoc networks. In *In Proceedings of the IEEE ICC*, pages 3201–3205, 2001.

[8] X. Li and L. Cuthbert. On-demand Node-Disjoint Multipath Routing in Wireless Ad hoc Network. In *29th Annual IEEE International Conference on Local Computer Networks (LCN'04)*, pages 419–420, 2004.

[9] H. Lim, K. Xu, and M. Gerla. TCP Performance over Multipath Routing in Mobile Ad Hoc Networks. In *In Proceedings of the IEEE ICC*, 2003.

[10] D. A. Maltz. *The CMU Monarch Projects Wireless and Mobility Extensions tons*. Monarch Project, monarch@monarch.cs.cmu.edu, snapshot release 1.1.1 edition, 1999.

[11] M. Molteni and M. Villari. Using sctp with partial reliability for mpeg-4 multimedia streaming. In *BSDCon Europe 2002. Amsterdam, Netherlands*, November 2002.

[12] M.R. Pearlman, Z.J. Haas, P.Sholander, and S.S. Tabrizi. On the impact of alternate path routing for load balancing in mobile ad hoc networks. In *Proceedings of the 1st ACM international symposium on Mobile ad hoc networking computing (Mobi- Hoc)*, Boston, Massachusetts, November 20 2000.

[13] C. Perkins and P. Bhagwat. Highly dynamic destination sequenced distance-vector routing (dsdv) for mobile computers. In *ACM SIGCOMMCommunications architectures, protocols and applications,Volume 24 Issue 4*, October 1994.

[14] C. E. Perkins and E. M. Royer. *Ad hoc Networking*, chapter Ad hoc On-Demand Distance Vector Routing. Addison-Wesley Publishers, 2000.

[15] Guanhua Ye, Tarek Saadawi, and Myung Lee. Sctp congestion control performance in wireless multi-hop networks. 2002.

