

## Mobile Internet Congestion Control

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### Abstract

*In this paper, we present a congestion control scheme for UDP-based adaptive flows, called PRDR (Proportional and Derivative). With application of PRDR, the sources have to adapt their transmission rate according to information about fairshare bandwidth and loss reported by the receivers in the RTCP reports. The PRDR algorithm uses a proportional and derivative controller to compute the fairshare bandwidth at router level. The performance study of PRDR in a mobile environment by simulations under ns-2 is presented.*

### 1. Introduction

With the emergent needs for the mobility of nowadays Internet applications and users in a constant move (mobile phones, PDAs, Laptops,...), wireless transmission has become an important issue in terms of traffic management and control.

Indeed, mobility can be supported in different layers of the Internet protocol stack and several architectures are proposed to handle the connection between correspondent nodes while moving: the aim of a mobility protocol is to keep the connection active even when one node changes from a network connection point to another.

Mobile IP [1], which has been standardized by the IETF (Internet Engineering Task Force), operates at the network layer: a mobile node has two addresses: the home address which characterises the original connection point to the home network, and the care-of-address which is assigned by the foreign network

With the emergence of new transport protocols that support multi-homing, another proposal suggests handling the mobility at the transport layer. Indeed, A TCP/UDP connection can be established between two corresponding nodes which are identified each by one IP address. A multihoming transport protocol can maintain a list of IP addresses for the

mobile endpoint of the connection. Two principal protocols are proposed in the literature: mSCTP (Multihome Stream Control protocol) [2] and mDCCP (Multihome Datagram control protocol) [5]. mSCTP is already an Internet standard, which works in a similar fashion to TCP-multihome. It is based on the SCTP protocol, expected to provide a reliable transport protocol for stream-oriented flows. mDCCP is derived from the DCCP, which motivation of is to afford a congestion-controlled and unreliable datagram flows. Moreover, it offers a reliable mechanism for connection setting-up and teardown. DCCP is well-suited for applications currently running over UDP that need to transport unreliable data flows. The work on mDCCP is still in progress

The UDP protocol (User Datagram Protocol) is known not to provide any congestion control, letting this requirement to the willing of the applications. Hence, misbehaving users would try to generate more traffic than supported by the network, which leads to network collapse and knock down. Many congestion control mechanisms [6, 7, 8] have been proposed for UDP flows, in order to maintain the network in a healthy working point and also a fair rate sharing between competing TCP and UDP connections.

The PRDR algorithm [10] (proportional and Derivative) that was proposed for wired UDP-based connections has shown good performances in terms of network stability and bandwidth fair sharing. PRDR is built on RTP/RTCP protocol [11] and operates at two levels: PRDR routers calculate a fair share along the path of the connection. This information is fed back to senders in RTCP reports. Then, the senders have to adapt their transmission rate according to loss situation observed in the network.

In this paper, we present the first design, which consists to implement the PRDR algorithm over a Mobile IP architecture, where mobility is supported at the network layer. In section 2, the dynamics of

mobile IP are described. Section 4 presents the PRDR algorithm as proposed in [10]. Sections 5 presents the heterogeneous (wired-wireless) mobile topology used in our ns-simulations. Results interpretation is done in section 6.

## 2. Mobile IP

Mobile IP is a protocol in the network layer, that allows transparent routing of IP datagrams to mobile nodes in the Internet. Each mobile node is identified by two IP addresses : a fixed home address and a temporary care-of address assigned by the foreign agent. A correspondent node sends datagrams to the mobile node knowing its home address. These datagrams are intercepted by the home agent and is tunnelled to the care-of address. The foreign agent then detunneles the datagrams and delivers them to the mobile node. Datagrams sent by the mobile node are delivered using standard IP routing. This mechanism, known as the triangular routing is illustrated in figure 1. Moreover, Mobile IP defines support services such as Agent Discovery and Registration mechanisms, involving the necessary authentication and security mechanisms.

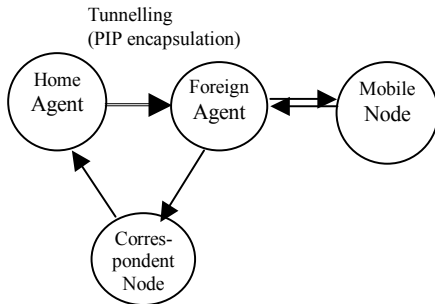


figure 1 . Triangular routing

The handoff occurs when a mobile node changes its current point of attachment. During this period, the connections involving the mobile node are interrupted. The main functionality of Mobile IP is to redirect packets destined to the mobile node safely during handoff, that is being able to keep the connections active while the mobile node is moving. This concept is very crucial for connection-oriented applications (TCP-based applications). Packets are often lost during handoff, since its duration is greater than the TCP timeout, connections cannot rapidly recover, which necessitates initiating the TCP slow-start.

Packet loss can be avoided using buffering technique at the foreign agent: it stores pending packets until it receives a previous Foreign Agent notification. Nevertheless, the Mobile Node may take a long time before finding a new Foreign Agent, and then losses contact with the previous

one. Consequently, Foreign Agent buffers overflows and packets are lost.

## 3. The PRDR Algorithm

The PRDR algorithm has been proposed for the flow control in ABR-service in ATM networks [12] and has been originally designed for packet-switched networks.

A switcher computes the local supported bandwidth using a proportional and derivative controller, having in mind the current and beyond occupancy of the buffering queue.

We have adapted in previous work the PRDR algorithm to UDP flows congestion control in the Internet [10]. We used the RTP/RTCP protocol to feedback control messages.

As depicted in figure 2, the source expresses its desired transmission rate in the RTCP control message. Each gateway on the connection path sets its value according to its available resources and forwards the control messages to the next network node until they reach the destination. The destination in its turn transmits the updated information back to the source who needs to adjust its transmission rate in accordance with the received information. The PRDR algorithm uses the RTP/RTCP protocol to convey the control information which avoids the need to introduce a new control protocol.

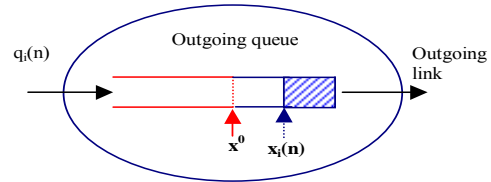


figure 2 . The PRDR Algorithm

For a given gateway  $i$  in the network, assume that  $x_i(n)$  is the average buffer occupancy of this gateway at time  $n$  and that  $x_i^0$  is a fixed buffer threshold. Then, to compute the admission rate at time  $n$ ,  $q_i(n+1)$ , the gateway uses a proportional and derivative controller which is defined by the following equation:

$$q_i(n+1) = \text{Sat}_{q^0} \left\{ q_i(n) - \alpha_0 (x_i(n) - x^0) \right\}$$

The rate calculation is performed every time a control packet passes the gateway, and the rate computed for the time  $n$ , given by the value of  $q_i(n+1)$  will be carried out in this control message. Then the minimum of all the  $q_i(n+1)$  on the connection is returned back to the source in the relative RTCP control message.

## 4. PRDR for Mobile Internet

Nowadays Internet grow-up, with the emergence of lossy wireless links, we assist to an increase of the delay-bandwidth factor, longer RTTs, asymmetric bandwidth paths and non congestion-related loss ratio (random loss). Thus, traffic reshaping and congestion control have to be considered in a different way from wired networks. Hence, congestion control mechanisms should be adapted, since network conditions and behaviour are different.

For instance, the PRDR algorithm, which operates in the routers, should be adapted to the new network conditions. It has to be implemented not only at wired routers, but also at wireless-link queues, that is in home and foreign agents (in the mobile IP context).

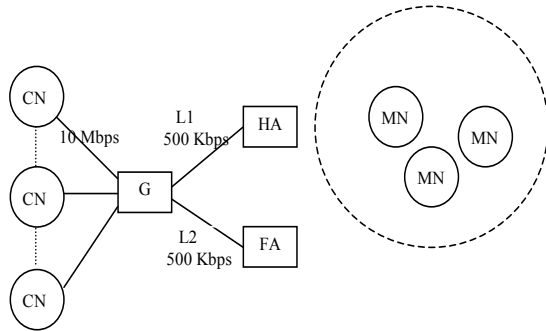
In fact, home and foreign agents present a bottleneck for the outgoing connections, since they are in charge to accept and forward packets destined to the mobile nodes.

We kept the same protocol stack architecture: we have implemented the PRDR on top of RTP/UDP transport protocol. Mobility is supported in the network layer by MIPv4 (ns module for MIPv4).

## 5. Network topology and test configurations

### 5.1. Network topology

Our tests were run on a heterogeneous topology (wired-wireless) depicted in figure 3: a number N of mobile nodes generate RTP traffic to N RTP sinks situated in the wired side.



CN : fixed RTP sink nodes  
MN: mobile RTP source nodes  
FA: Foreign Agent  
HA: Home Agent  
G: Gateway

Fig 3 . Network topology

A gateway G is placed between home and foreign agents on a side and the RTP sinks on the other side.

The PRDR algorithm is implemented at foreign and home agents and at the gateways. The links are shared by N RTP flows, which are generated by CBR (Constant Bit Rate) applications.

For the PRDR algorithm, we used a value of 15 packets for  $x^0$  and 0.8 for  $\alpha_0$ .

For all configurations, the DSDV routing protocol is used.

### 5.2. Test configurations

In order to investigate the performance and behaviour of the PRDR algorithm, we have tuned various parameters on the topology described before. This variation represents the following network states:

- Light congested network
- Heavy congested network

For both configurations, the simulation time was of 900 seconds. Simulations have been carried out using the ns-2 simulator, by consolidating its RTP modules in RTP agents, specifically for the exchange and the processing of the RTCP control messages.

## 6. Simulation results

### Configuration 1

In this configuration, we are interested in the scalability of the PRDR algorithm in a mobile environment. For, the simulated topology discussed above consists of a single RTP connection between a mobile RTP source node and a fixed RTP sink node. We have created a congestion state by setting the link L1 and L2 capacities to 500 kbps while the mobile node's initial transmission rate is 5 Mbps.

Figure 4 illustrates the instantaneous RTP rate when the PRDR algorithm is applied. As we could observe, the RTP transmission rate begins at 5 Mbps, and it decreases until reaching the value of 400 kbps as soon the simulation starts.

The RTP rate starts to oscillate between the fairshare rate Q which is given by

$$\frac{\text{Link capacity} \times 0,8}{\text{Number of connections}} = 400 \text{ kbps, and the}$$

maximum link capacity 500 kbps, according to the loss states which have been observed.

This is due to the source adaptation mechanism: when the RTCP loss flag field is set to 1, the source is restricted to transmit only at the fairshare rate, when the RTCP loss flag is set to 0, the source is allowed to increase its transmission rate.

Moreover, the system has a fast reaction to heavy congestion and succeeds to reach a steady state.

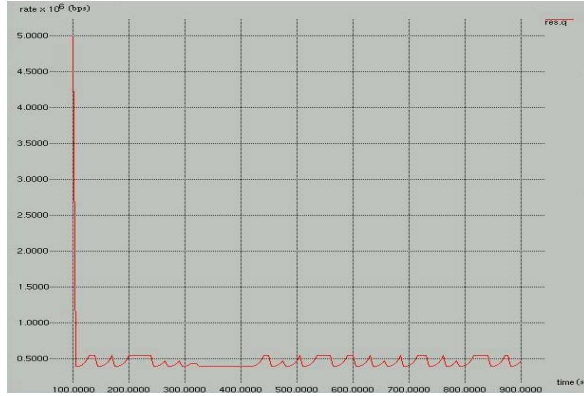


Figure 4 . Rate Adaptation Scene1

## Configuration 2

In this configuration, the bottleneck links are shared between 5 connections, initiated between 5 mobile RTP source nodes and 5 RTP fixed sink nodes. RTP sources start to transmit at different times, at intervals of 50 seconds.

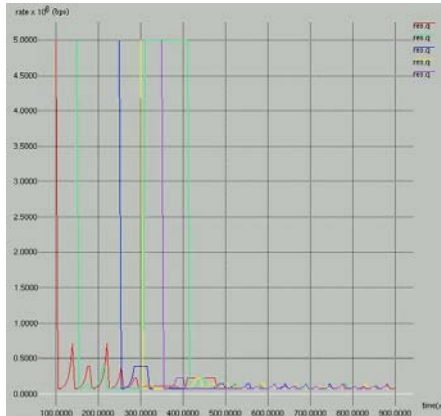


Figure 5 . Rate Adaptation Scene2

As plotted in figure 5, when a single flow is active, its transmission rate reaches 500 kbps. When all flows are activate, the minimal fairshare rate is set to 80 kbps. Mobility starts at 400s, and since, the RTCP loss flag is set to 1 until the end of the simulation. This is due to the incapacity of the PRDR algorithm to distinguish between congestion losses and random losses, which are due to mobility.

## Configuration 3

Here, we are interested in the PRDR fairness towards competing TCP flows (TCP-friendliness). In this configuration, we are in presence of 5 mobile RTP and 5 mobile TCP source nodes. In a first time, we run the simulation without use of the

PRDR algorithm, and then we applied the PRDR in a second time.

The figures shown below represent the instantaneous TCP congestion window's variation respectively without and with PRDR control.

The TCP connections behaviour in presence and absence of the PRDR control is summarized in tables 1 and 2. In the first table are shown the maximum congestion windows achieved by the five TCP flows. The second one involves the first congestion times for each flow.

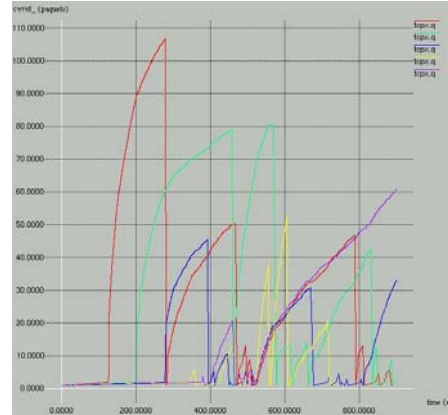


Figure 6 . TCP congestion window Scene3 without PRDR

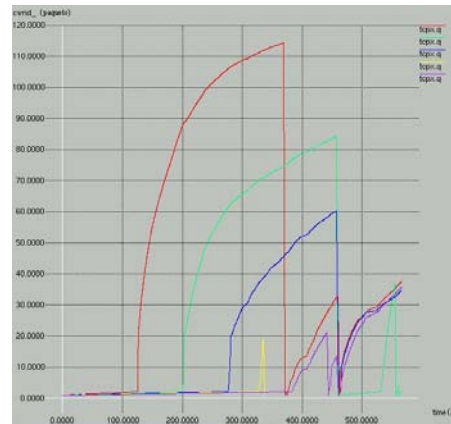


Figure 7 . TCP congestion window Scene3 with PRDR

	Without PRDR(in seconds)	With PRDR (in seconds)
N1	107	115
N2	80	85
N3	46	60
N4	51	19
N5	20	21

Table 1. TCP Congestion windows

	Without PRDR (in seconds)	With PRDR (in seconds)
N1	280	380
N2	460	470
N3	395	470
N4	380	340
N5	450	455

Table 2 .First Congestion times

Obviously, all TCP window sizes increased when using the PRDR algorithm, and congestion state was backed off as late as possible. Moreover, the system achieves a steady state in a short period of time.

## 7. Conclusion and further work

In this work, we have adapted the PRDR congestion control algorithm to a mobile environment. As shown in performance evaluation by ns-2 simulation, we have demonstrated that the PRDR algorithm shows good performances under such networks since it succeeds to insure good fair-share between TCP and UDP flows. Moreover, the PRDR algorithm provides a rapid convergence to a steady system state.

Nevertheless, the network model used to perform this work is quite simple, that's why we will continue to investigate the PRDR performance on more complete and realistic configuration such as the string and Mesh ones. Besides, we will test the performances of the PRDR algorithm in presence of moving nodes.

## 8. References

- [1] C. Perkins, "IP mobility support", RFC2002, IETF, Oct. 1996.
- [2] Seok J. Koh, , Qiaobing Xie. mSCTP with Mobile IP for Transport Layer Mobility. (IETF Internet-Draft draft-sjkoh-mobile-sctpmobileip-03.txt), November 2004.
- [3] L. Ong, J. Yoakum. An Introduction to the Stream Control Transmission Protocol (SCTP). RFC3286 IETF NetworkWorking Group, May 2002.
- [4] Eddie Kohler, Mark Handley, Sally Floyd, Jitendra Padhye. Datagram Congestion Control Protocol (DCCP). (IETF Internet-Draft draft-ietf-dccpspec-09.txt), November 2004.
- [5] Eddie Kohler, Datagram Congestion Control Protocol Mobility and Multihoming, (IETF Internet-Draft draft-kohler-dccp-mobility-00.txt ), July 2004.
- [6] G.-S. Ahn, A.T. Campbell, A. Veres and L.-H. Sun, SWAN: Service Differentiation in Stateless Wireless Ad Hoc Networks, *IEEE INFOCOM 2002*, New York, NY, June 2002.
- [7] S.-B. Lee, G.-S. Ahn, X. Zhang, and A.T. Campbell, INSIGNIA: An IP-Based Quality of Service Framework for Mobile Ad Hoc Networks, *Journal of Parallel and Distributed Computing*, 60(4), 2000, pp.374-406.
- [8] Vicente E. Mujica V., Dorgham Sisalem , Radu Popescu-Zeletin and Adam Wolisz : TCP-Friendly Congestion Control over Wireless Networks, *Proc of European Wireless 2004*, Barcelona, Spain, February 2004.
- [9] B.P. Crow, I. Widjaja, J. Geun Kim and P.T. Sakai, "IEEE 802.11 wireless local area networks", *IEEE Communications Magazine*, vol. 35, no. 9, pp. 116-126, September 1997.
- [10] Abir Ben Ali, "Congestion Control for Multimedia Applications in the Internet", Master Project, National School of Computer Sciences, Tunisia, may 2004.
- [11] H. Schulzrinne Casner Frederick V. Jacobson, "RTP: A Transport Protocol for Real-Time Applications", IETF RFC 1889.
- [12] I. Lengliz F. Kamoun, "A rate-based flow control method for ABR service in ATM networks," *Computer Networks*, Vol. 34, No. 1., pp. 129-138, July 2000.