VIRTUAL ROUTERS- A TOOL FOR NETWORKING RESEARCH AND EDUCATION

Dr.R. Saravana Moorthy

Associate Professor and Head, Department of Computer science
Kongunadu Arts and Science College, Coimbatore - 29.
Email. rsaravanamoorthy_cs@kongunaducollege.ac.in

ABSTRACT

Virtual routers are software entities, i.e. user space processes, emulating IP routers on one or several (Linux) computers. Virtual routers can be used for both networking research and education. In contrast to simulation, virtual routers process packets in real-time and the virtual router code are similar to code in real routers. In the case of research, larger network test-beds can be built using a relatively small number of computers. New functionalities such as new queuing mechanisms are supported by a modular software architecture and can be tested in a rather safe environment compared to kernel space implementations. Virtual routers can also be used as a tool aiming to allow students to perform virtual experiments within a computer networks course. Students can create and experiment with arbitrary virtual IP network topologies. The web-based user interface allows students to interact remotely with the emulated routers, but simultaneously it is very similar to commonly available configuration interfaces of network devices in reality. This enables students to configure routers like in the real world but also to experiment in a much more robust and safer environment.

INTRODUCTION

The strengths and drawbacks of network simulators, like the ns network simulator, lie in the use of a mathematical model to simulate a network, a node or a link between two nodes. Since there is no relationship between real time and the time ns uses internally, ns can be used to run huge simulations with thousands of nodes and links. The simulation simply will last longer, but is nevertheless mathematically correct. The use of such a model includes a rather abstract view of a network consisting of nodes and links. These properties are sufficient to simulate the traffic flow of thousands of nodes within a huge network.

For the development of new network protocols, however protocol implementations should be closer to real system environments and real-time packet processing is desirable in order to support a larger variety of performance evaluations. In particular, it would be advantageous if new functionalities can be tested in real environments with typical applications and network scenarios. Another requirement

appears for networking education. Students should be able to perform practical networking experiments, but at least for early steps safe and robust laboratory environments are desirable.

Both of these application scenarios, i.e. research and education, are supported by a concept called virtual routers. Virtual routers emulate IP routers and can support flexibility and robustness by a modular software architecture and user space processing. We propose to use emulated routers not only for research and development, but also for distance learning allowing students to perform computer network experiments remotely and within a safe environment. This allows students to prepare themselves for later experiments that are performed remotely with real network devices. Remote experiments are very popular in various areas such as nano-science, engineering, computer networks etc.

A. Virtual router Networks

Virtual Routers are software entities that emulate IP routers. Virtual routers are connected by communication channels to create larger networks. Virtual routers run as independent process not interfering with other virtual routers. They enhance packets through communication channels.
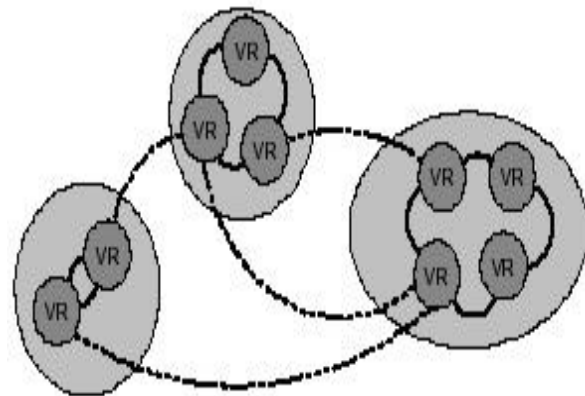

Network of Virtual Routers

Distribution and interconnection of several virtual routers in three different computers is shown. The type of the communication channel that connect two virtual routers depends on whether they run on the same computer or on different computers. Virtual routers running on the same computer are interconnected by interposes communication whereas virtual routers running on different computers are interconnected by UDP channels.

Virtual router traffic is real time. They also receive, process and forward packets. Virtual routers can also be connected to real networks. This traffic can be routed through both real and emulated sub networks. The Virtual Routers can be connected to real networks using soft link devices. Packets transmitted over the soft link devices are transmitted to a Virtual Router. In the opposite direction packets transmitted from the Virtual routers are routed to TCP stack on top of softlink device.

B. *Implementation*
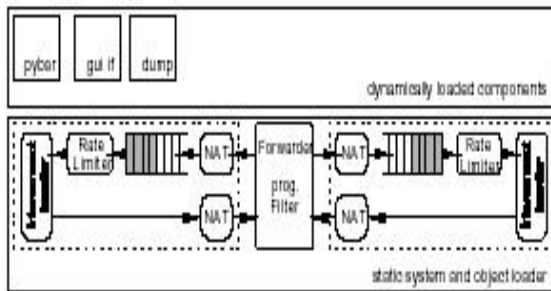
Virtual Router Implementation Architecture

The architecture includes interface represented by dotted lines and a programmable filter and forwarding unit. IP packets are received and transmitted via interfaces. Interfaces consist of several configurable subcomponents such as Network address translators(NATs), queuing system, rate limiters and interconnection handlers. An interconnection handler connects Virtual routers with other Virtual routers and softlink devices. The packet received from an interface are procesewe4d by a programmable filter and forwarding unit. Virtual routers can be extended by dynamically loadable objects such as an active router extension(Python Based Active Router, PyBAR), a graphical user interface (command line interface), a traffic monitoring component (dump) etc. The central unit of Virtual Router is the event scheduler, where most of the router's components are registered and which schedules the events.

Multiple process running on single computer needs synchronization between process. Oscillation can exist between different routers due to the interface between operating system process schedular and event scheduler of the Virtual routers. The oscillation effects can be eliminated by the randomization of simultaneous events.

Another important part of the Virtual Router is the queuing system. The set of components in the queuing system are queues, filters, shapers, schedulers etc:- These components can be loaded, combined and configured which allows the replacing of complete queuing system of Virtual Router during run time without shutting down a running network emulation process.

Application Programming Interface(API)

Virtual routers provide very degree of flexibility: Interface components can be created and modified dynamically, higher layer objects can be loaded dynamically, filters are programmable, and routing tables can be adapted. To support this flexibility, virtual routers support different configuration interfaces by API channels. The configuration program such as a graphical user interface has to establish an API channel to the virtual router and can exchange configuration messages over this duplex channel.

VIRTUAL ROUTER PERFORMANCE

Link and Queuing Delay

Since Virtual Router processes packets in real time changes in processing speed of the computer will affect the packet delay. The link delay is defined by the computer processing power. The delay in Virtual Routers is compared with other networks and the results are as shown below

|	hops	RTT [ms]	per hop [ms]	congestion
D	15	38	2.53	unknown
D	15	32	2.13	unknown
CH	8	4.5	0.56	Small
VR	8	2.1	0.26	No
VR	16	4.3	0.29	No
Linux-DS	8	75.46	9.433	Heavy

DELAYS IN DIFFERENT NETWORKS

Since measurements within Virtual routers are made in an unloaded network, the delay is caused only by the link delay and packet forwarding within Virtual routers. Also the queuing in Virtual routers is responsible for packet delays. This delay can be demonstrated with interface speed at 4Mbps and different transmission rates. When queue was empty, delay is small. When incoming bandwidth increases delay also increases. Once queue starts dropping packets, the delay remains constant.
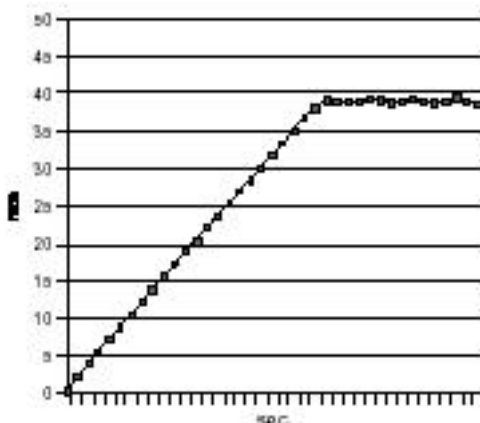
Delay of a virtual router FIFO queue using a 4 Mbps link

1) Impact of Processing Overhead to delay

Processing overheads also affects d3elay. This can be communication overhead or computer workload. This can be measured with two different router connection as shown below
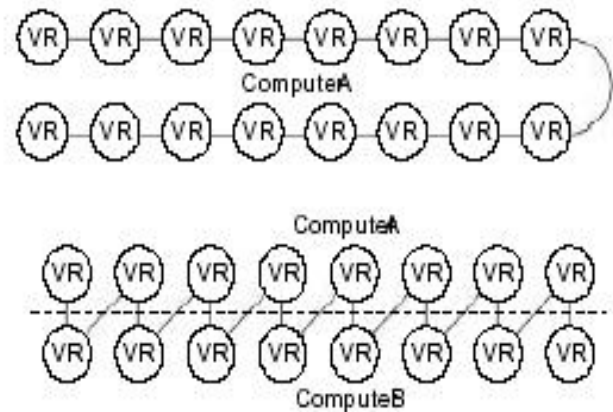

16 virtual routers on one computer (upper part) and on two computers (lower part)

In the first connection 16 Virtual routers are in a single computer and in the second figure 16 virtual Routers are in two computers. Both loaded and unloaded situation are evaluated for delay. In the unloaded situation the round trip time is higher for the distributed cases compared to virtual routers in single computer. This increase in round trip time in distributed case may be due to the delay involved during the encapsulation into UDP packets and forwarding. The round trip time increases slightly when the evaluation is done in a loaded situation.

Further it is evaluated that the topology size does not have significant effect on

packet forwarding and link delay. This is clear when 16,32 and 64 routers were run on a single computer. The effect on number of Virtual Routers on round trip time in unloaded network is as shown below.
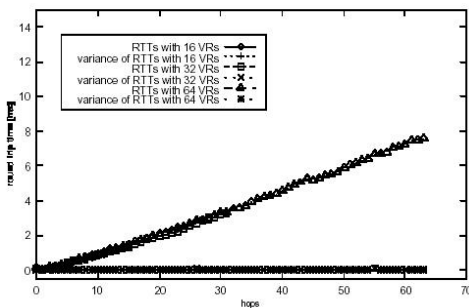
Round trip times with different numbers of virtual router entities in an unloaded network

But when the network is loaded, larger topology causes longer delay. Thus the maximum number of Virtual Router on a single host is limited not only by the processing power, but also on the traffic load within the emulated network, the bandwidth of virtual Router interfaces, complexity of queuing system and on the accuracy of the results.
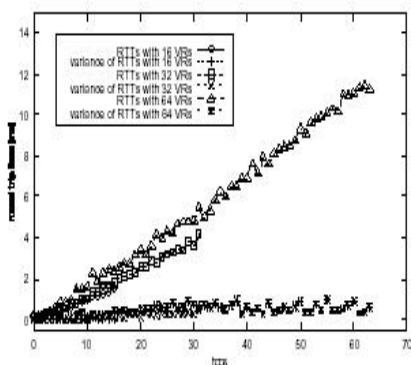
Round trip times with different numbers of virtual router entities in a loaded network

Virtual Routers For Networking Research

Evaluation of Queuing Components

Although the original idea of virtual routers was to provide a platform for the development and evaluation of mechanisms such as network management and Quality of Service routing, the architecture also offers a suitable test-bed for traffic measurements.

Active Networking

Another application area for virtual routers is the development of new networking mechanisms and protocols

Virtual Routers for Distance Learning

Virtual routers offer a platform for rapid development, prototyping and testing of new communication subsystems but also can serve as a platform for distance learning. Virtual routers not only help to keep the costs for building large experimentation networks very low but also offer a robust environment for performing network device configuration exercises.

Related Future Work

Emulab is an ongoing project providing a large test-bed for the emulation of networks. The test-

bed can be accessed remotely and provides mechanisms to use ns2 scripts for the configuration of the test network. Several other approaches such as the Click modular router is a highly modular and well performing software router implementation, which allows the emulation of a very flexible, easy to configure router on a single computer.

There are other more specific approaches to emulate the typical behavior of a special network device (e.g. a WAN Router) or a specific link. NistNet uses Linux kernel modules to emulate the behavior of a specific link and allows the emulation of WANs within a standard laboratory LAN.

SUMMARY AND CONCLUSIONS

The paper described the concept of virtual routers, which can be used to emulate multiple routers on a single computer. The virtual routers as the basic underlying components have been successfully used for several research purposes, in particular for research projects in the area of Quality-of-Service management and monitoring as well as active networking. Virtual routers are also very useful in order to provide safe, robust but realistic experimentation environments for students in a networking class. Students can prepare themselves for later experiments with real network devices.

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