WHITEPAPER

Lucent Technologies
Bell Labs Innovations

Lucent Technologies
Remote Access Business Unit

ComOS

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1.0 Executive Summary

With millions of ports enabled in support of tens of millions of dial-up users, ComOS® is the most widely used remote access server (RAS) operating system (OS). ComOS was originally developed in the early 1990s to meet the special requirements of remote access networks, which are unique because they reside "on the edge" of larger networks. These "edge" networks provide end-users with points of entry into much larger, often public, networks. Since its inception, ComOS has maintained an exclusive focus on remote access routing and the Internet protocol (IP) - including requirements for routing, authentication, and packet filtering. Because of its inherent support for distributed hardware architectures and centralized management, ComOS is the linchpin for reliable, scalable, and managemeable remote access solutions.

2.0 ComOS Overview

Commitment to the success of the customer differentiates Lucent Technologies from many of our competitors. This commitment and the close customer relationships that result drive our product development. The robust feature set and functionality built into ComOS are excellent examples of this process in action.

"Over the years," explains Steve Willens, President of the Remote Access Business Unit, "we've layered incredible depth and flexibility into ComOS – to such a degree that most customers don't even know the extent of features that it currently supports. Customers do know that ComOS enables one feature they like best about Lucent PortMaster® products–that you can configure a PortMaster, put it in your network, and forget that you own it."

Four factors have significantly contributed to the superior performance, reliability, and ongoing popularity of ComOS among Internet service providers (ISPs): maturity, interoperability, modularity, and a common user interface.

2.1 Mature Product

ComOS is the most mature RAS operating system available. We've been involved with the remote access industry from the beginning. Other vendors face a tremendous challenge in trying to build from scratch today what we have been refining since the first modem was connected to a telephone line.

In 1992, for example, we created the original client-server RADIUS (Remote Access Dial In User Service) technology to automate real-time authorization, authentication, and accounting (AAA) and to reliably collect network usage information for post-processing. Today, RADIUS is the de facto industry standard (RFC 2138), used by RAS vendors worldwide. The RADIUS client is a fundamental component of ComOS.

From the very beginning, we and our customers have tested and retested our products until we know our software and hardware platforms can handle nearly every remote access feature imaginable. And, before we add a new feature, we make sure it won't break any of the critical functions already supported by ComOS.

2.2 Interoperability

Commitment to our customers' success has required us to work cooperatively with other vendors to detect, anticipate, and adjust to changes in their products and ensure their interoperability with our products. Because we work with nearly 3,000 customers in 78 countries, we are able to make a strong commitment to the interoperability of our RAS products in virtually every environment and with every industry-supported protocol.

Because we believe it's so important for our products to interoperate with those from other vendors, some features of ComOS go beyond the details and Requests for Comments (RFCs) from the Internet Engineering Task Force (IETF). RFCs leave specific implementation options open. To achieve optimal

performance and interoperability, Lucent works to make sure that ComOS adjusts to the implementations of different vendors. Even in cases where vendors' products do not conform to standards, ComOS adapts to achieve interoperability.

2.3 Modular Architecture

ComOS uses a modular architecture. While not technically "component-based", the overall result is the same. Each module targets a specific feature set. And, for any given task, ComOS uses only the specific module it needs. This approach is significantly more efficient and radically different from the operating systems of other vendors, which can auto-activate extraneous modules and consume valuable central processing unit (CPU) resources.

What's more, the modular nature of ComOS allows our developers to write code for new features without knowing much about ComOS itself. They can focus on the specific task at hand and write extremely tight code that can immediately take advantage of all the other capabilities within ComOS.

The benefits are clear. For instance, one leading vendor's operating system requires 64MB of memory to run Border Gateway Protocol, Version 4 (BGP4); ComOS requires only 16MB. Further, BGP4 routines are extremely CPU intensive and can easily overload the system. ComOS, by limiting everything outside of the data path to no more than two percent of CPU capacity, ensures that no single module or routine can cause bottlenecks or congestion that might affect other users.

Thus, the modular architecture of ComOS allows us to deliver new capabilities more efficiently, more quickly, and more reliably than other RAS vendors.

2.4 Common User Interface

ComOS has a common administrative user interface and well-known feature set that work consistently across all PortMaster hardware products. This commonality simplifies the management of all resources within each product, including everything from our small-office/home-office (SOHO) Office Routers to our carrier-class PortMaster 4 Integrated Access Concentrators.

The command line interface (CLI) of ComOS is consistent and stable. Even when a new feature is added, users of our earlier versions of ComOS are able to immediately recognize the commands and routines needed to access that feature. By entering a dozen familiar commands, our customers can always get their new PortMaster product up and running in a matter of minutes.

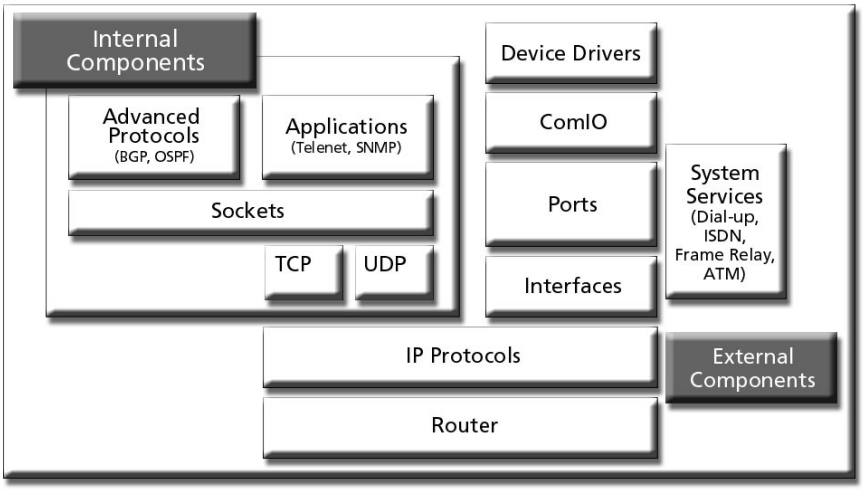

Figure 1. ComOS Kernel

3.0 ComOS Structure

Figure 1 illustrates the internal and external components of the ComOS kernel, which contains the core feature set for remote access functionality. Common input/output (ComIO) processes shown in the figure provide communication between device drivers and PortMaster ports, while interfaces connect ports via protocols to the network. For simplicity, the specific number and types of ports that can be supported by the ComOS kernel are not specified. The applications, system services, and advanced protocols shown in the diagram are cited as typical examples.

As new ComOS software features are added or modified, updates are continuously posted to the Remote Access Business Unit's website and can be downloaded by any PortMaster owner of record.

3.1 Management Functions of ComOS

All ComOS management commands are entered at the command line interface, either directly through an asynchronous port or through a Telnet to the PortMaster, once the unit's IP network address has been set. Command line management requires no software installation.

Alternatively, ComOS commands may be entered through the PMVision™ graphical user interface (GUI) management utility available with every PortMaster product. Java-based PMVision provides platform-independent access to the following main system functions of ComOS:

- Configuration
- Viewing (monitoring)
- Installation and upgrade
- Backup and restoration
- Troubleshooting and fault isolation

PMVision is constantly being improved with wizards and smart agents. The user can administer an entire point of presence (POP) from a single workstation by doing the following:

- Monitor diagnostic events and status
- Change signaling for a specific line for analog and ISDN calls over a single T1 line
- Enable data-over-voice transmission
- Manage multiple PortMaster units simultaneously

PMVision provides all configuration options available through ComOS for a PortMaster running ComOS 3.8 or later. In addition, this utility lets the user copy a configuration from one PortMaster to another, diagnose problems, and enter ComOS commands through a PMVision window.

3.1.1 Configuration Management

A PortMaster remote access device initializes its system configuration in the following five stages - performing diagnostics, locating its IP address via BOOTP or RARP, loading ComOS, initializing devices and ports, and loading the user configuration. The entire startup process takes less than a minute.

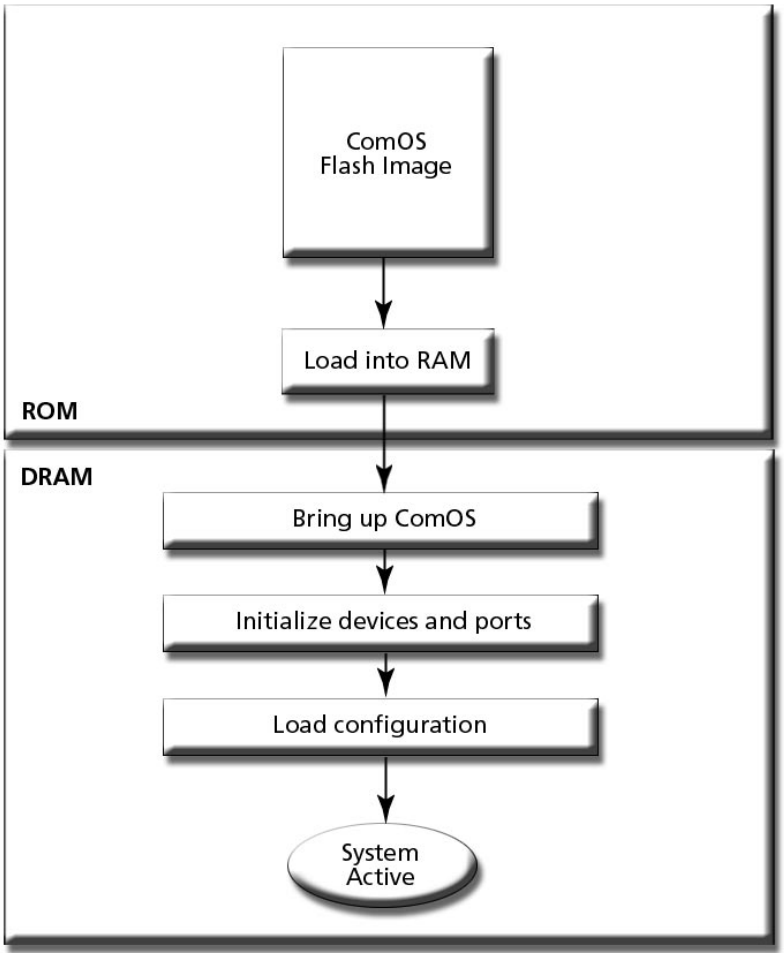

Figure 2. PortMaster Initialization

Figure 2 shows the initialization sequence for a PortMaster product, starting with the Flash image of ComOS in read only memory (ROM) and concluding with full system activation in dynamic random access memory (DRAM).

Factory-installed on all PortMaster products, ComOS is stored as a compressed file in nonvolatile RAM (NVRAM), sometimes called *Flash memory*. During the initial startup process, the PortMaster uncom-

presses and loads ComOS into DRAM. Once successfully started, ComOS enables the following:

- Ethernet interfaces
- Asynchronous ports
- Modems
- Dial-out connection profiles
- Configuration of routing support for interfaces
- Transmission Control Protocol (TCP) connections to hosts and ports configured as host devices
- Listening for TCP connections to ports configured as network devices
- Listening for activity on TCP and User Datagram Protocol (UDP) ports such as Telnet sessions on the TCP port or Simple Network Management Protocol (SNMP) requests on the UDP port

During startup, ComOS enables any other services that may have been configured such as syslog, RADIUS, and ChoiceNet® filtering. Once the initiation phase is completed, working through the console port on a PortMaster product, a system administrator can begin configuring settings across all of a PortMaster unit's ports and interfaces. This includes settings for an administrative password, default routing, static routes, and authentication for dial-in users.

3.1.2 Remote Network Management

Network management is accomplished through ComOS via SNMP and a variety of tracing, monitoring, and diagnostic facilities. ComOS enables Lucent Remote Access staff to connect to and diagnose a PortMaster remotely located anywhere in the world. When necessary, our engineers can also remotely debug ComOS code. These capabilities can significantly cut network downtime and management costs, especially for customers with geographically dispersed POPs and branch offices.

ComOS allows customers to upgrade a PortMaster product without taking the system out of service during the upgrade process. The system can be scheduled to load the upgrade at a specified time, thus minimizing downtime. In fact, some module upgrades entail no system downtime at all.

Recent implementations of ComOS on our PortMaster 3 products let users hot-swap modems to ensure uninterrupted remote access service and reliable dial-up port connections. On the PortMaster 3 and PortMaster 4 products, ComOS also enables the establishment and maintenance of modem pools to enhance traffic capacity and reliability. Digital signal processor (DSP) pools can be shared to support data, fax, and voice traffic.

3.2 Telco and Routing features of ComOS

As is shown in the table below, ComOS supports a full suite of telecommunications signaling features. These include Frame Relay (FR), Asynchronous Transfer Mode (ATM), nonfacilities-associated signaling (NFAS), D-channel signaling, channelized T1 and E1, leased lines, Integrated Services Digital Network (ISDN), and R2.

Functionality	Protocols
Full IP stack:	UDP, TCP, ICMP
IPX stack:	IPX, SAP, SPX
WAN:	PPP, RIP, OSPF, BGP4
Application:	Telnet, Rlogin, PMD (PortMaster daemon)
Services:	DNS, NIS, BOOTP, TFTP, RADIUS, DHCP, syslog
Management:	SNMP, INPMD
Advanced:	VPN, MCP, IPIP, V.120, X.75, L2TP, PHS

Table: ComOS - supported protocols

ComOS also provides robust routing support, including packet filtering and the IP and IPX versions of the Routing Information Protocol (RIP) versions 1 and 2, and BGP4. In addition, ComOS supports Open Shortest Path First (OSPF) protocol with variable-length subnet masks (VLSMs), which enable the segmentation of one class A, B, or C address into many subnet addresses of different sizes for use in multiple POPs. The easy-to-configure VLSM support lets network administrators allocate scarce IP addresses more efficiently.

3.3 Opertaing System Features of ComOS

Although ComOS is a mature product that incorporates a comprehensive and highly complex set of remote access features and functions, it has been designed for maximum efficiency and reliability. Three critical design factors contribute to the superior performance of ComOS:

Non-Preemptive Real Time Operation: ComOS is designed to process all packets to completion, with priority given to data movement and processing. The simplified OS increases reliabitity and reduces risks when new features are introduced.

Remote Diagnostics: ComOS is unique in the industry because it enables a network administrator to diagnose a remotely located RAS through a local PortMaster console. Companies that have offices across borders or even across continents can manage their networks from a single central headquarters site, thus maximizing network uptime and avoiding the costs associated with dispatching field service personnel to remote locations.

Scalability: ComOS scales linearly because it supports multiple distributed processors. Therefore, as traffic load increases, performance efficiency is maintained. This capability is probably most dramatically illustrated in the way ComOS runs on the Remote Access Business Unit's PortMaster 4 Integrated Access Concentrator.

Each board in the carrier-class PortMaster 4 contains one or more CPUs. ComOS runs distributed across all of these CPUs. ComOS therefore extends the advantages of parallel processing. The processing, filtering, compression, and packet-forwarding decisions are made on each board for its own ports. As boards are added, the processing capacity scales along with the interface capacity.

Distributed processing enables the PortMaster 4 to scale up performance as need arises. Each board in the chassis can offload multiple RAS functions from the CPU - including packet forwarding and filtering, PPP framing, and Stac-based compression. This type of operation permits full media-rate routing, even under heavily loaded conditions.

4.0 Conclusion

The original developers of ComOS understood the importance of a software platform that supports a real-time operating system in a run-time environment, one that can accommodate any hardware, software, or protocol functions that might evolve in the future. Unlike competitive products that use a complex instruction set to enable "everything but the kitchen sink," ComOS is optimized for speed and efficiency in the demanding environment it was designed for.

ComOS and all PortMaster products have been developed to provide the central management, reliability, security, interoperability, and scalability that Lucent Technology customers need to efficiently manage the rapid growth of their businesses now and into the next century.

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