The PackeTen® System
The Next Generation Packet Switch

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Abstract

This paper examines the current digital bandwidth crisis which is plaguing amateur packet networks, and details a project in the Chicago area which addresses the problem. The PackeTen® project was conceived to provide a "next generation" hardware and software platform capable of satisfying both the current crisis and to allow for many future enhancements. The system described is a working implementation of the long awaited truly "high-speed" packet switch that is available for general use today.

During the last several years, packet radio has become one of the fastest growing segments of amateur radio. In fact it seems that very few of us have not at. least given it a try. Since the infancy of this mode, we have seen it grow from simple keyboard to keyboard conversations (similar to early RTTY operations), to store and forward electronic mailing systems, and even simple networking/routing systems.

This means of information transfer under machine control has made electronic mail an accepted part of the radio amateur's day to day operations. As we became more comfortable with the use of digital communications (in applications such as e-mail), we began to see more and more users on our crowded network channels. At the same time, many packet users began to develop an appetite for more sophisticated networking applications. In fact it is now becoming relatively common for individuals to exchange larger amounts of data! in such forms as computer programs, digitized audio and video images, and on-line applications. Applications such as computerized callbook servers, conferencing bridges, and remote file servers. are also being experimented with.

This combination of large numbers of on-line users and sophisticated applications has now produced a sort of crisis within our amateur packet networks. The one thing that all of these network users have in common is that each is a consumer of digital bandwidth within the network. Every day as we see new users on the channels, and new software applications. we also see our networks becoming more overloaded and less enjoyable to use. This problem of inadequate network resources has already begun to reverse the trend of innovation which we experienced in the early 80's. Many of our networks are overloaded to the point of breaking by the volume of electronic mail alone, and with more traffic being generated everv day by a larger contingent of users, there is no end in sight. Instead of growing and improving. our networks are beginning to sag under their own weight.

One reason for the rapid expansion of packet networking via radio is that it represents an area of electronic technology which is open for experimentation. However, these adverse conditions have also begun to stymie the efforts of those experimenters who are trying to provide new applications for the network. For example, it is of little value to have a local conferencing bridge, if the average response time is measured in tens of seconds. The initial excitement over the new application would soon die out because it was too painful a process to be useful or enjoyable. However, if the network was sufficiently responsive. it is probable that this application would find widespread use.

Over the last three or four years, considerable interest has been generated in the idea that it soon might be possible to develop amateur digital networks with the ability to move these large amounts of data in a timely fashion. This idea was based on several factors. The first is that microprocessor technology is becoming increasingly more powerful and less expensive, allowing the development of more advanced networking architectures. The second is that modem technology is becoming available which allows higher data rates while utilizing minimal spectrum. The last major factor in this equation is the development of the increasingly sophisticated software systems needed to support our growing network requirements.

These new technologies promise to provide network system designers with all of the ingredients to build the higher performance networks which are needed today, as well as providing a base for future expansion and improvement.

Surprisingly however, several years after it's introduction in the early 80's, the mainstay of the amateur packet community is the standard 1200 baud TNC-2. Why is it that we haven't advanced to the much superior technologies which are available todav? During the above mentioned period, software systems capable of handling new sophisticated applications have indeed become a reality and are in common use today. However, available hardware technology remains a problem.

Modem technology has advanced considerably since the introduction of the TNC-2. We have seen the development of the K9NG 9600 bps modem, and it's variants, as well as the WA4DSY 56k bps radio/modem, and most recently even a system for a full megabit per second data link. as described by Glen Elmore. N6GN, in Ham Radio Magazine. December 1989. These advances have met with limited success for various reasons. However, for systems operating at rates of 56 kb/s, or higher? one of the big problems has been the lack of digital communications hardware capable of handling the higher data rates. In fact, the WA4DSY modem / radio system has been available for over two years, but, with no good solution to the digital problem. it has not achieved the success which one might expect.

Several prototype digital hardware systems have been constructed and tested over the past few years. with varying capabilities, but none have been made available to the general ham community. This situation prompted the authors to design and make available a digital hardware system capable of addressing the packet networking requirements of both current and future systems.

The PackeTen svstem is designed specifically to address the needs of a high speed data switching node. It was initiallv conceived to solve the network overload problems in the Chicago area. where the K9NG modem based 9600 bps backbone was, at times, overloaded by the sheer volume of mail traffic alone.

Design Criteria Of The PackeTen® Switch

- Data rates in excess of 1 megabit per second.
- Total aggregate throughput of at least 1 megabit per second.
- Five or more channels.
- Operation from EPROM or RAM.
- A standalone version for " mountain-top' applications.
- Non-volatile memory to support re-boot and auto-configuration.
- An IBM PC XT/AT compatible version with high-speed file access.
- Large code space and data space.
- A port of KA9Q's NOS (latest version of KA9Q's TCP/IP system) in ROM, "NOSINABOX", so the average radio amateur can bring-up the packet switch immediately.

The design goal was to provide a digital hardware and software system capable of handling large amounts of data with a capacity adequate for both now and the forseeable future. immediate requirements dictated that the system handle at least three 56 kbps links utilizing the WA4DSY radio/modems to implement the "cellnet" concept (described by Don Lemke in the 1987 CNC proceedings) here in the Chicago area. However, since 56 kbps is not sufficient bandwidth for the envisioned networks of the future, we perceived a need to handle several channels running at multi-megabit rates for this system to be the packet switch of choice for the early 90's.

Overall system throughput was of paramount concern. The completed system must be adequate to handle such applications as realtime digitized voice channels, and internetworking of computer resources as well as more typical data communications functions such as electronic mail, file transfers, callsign database servers etc. In order to meet these requirements, the system must be capable of a minimum total aggregate throughput in excess of a megabit per second.

Since it was envisioned that this system would be used as the major internetworking component for our growing needs. it was decided that minimum capabilities wouid include support for multiple high-speed channels to allow for network growth. Additionally, in order to provide access to the network. the system should provide lower speed user access channels at more conventional rates such as 1200 to 9600 baud. After some debate we settled on a 10 channel system providing 6 high-performance networking channels and 4 local access ports.

Another concern was the necessity to provide adequate system memory resources. In order to develop sophisticated software systems with- large program and data memory requirements, the hardware must provide a healthy complement of memory in the minimal configuration with lot's of expansion capability built in for the future. Also since the system was to have a standalone configuration, some form of non-volatile storage was required. (If the standalone system resets (e.g. a power failure, etc.) the non-volatile memory is used to auto-configure the system at startup.)

Another major design consideration was that the system operate from a single 5v supply, and require very small amounts of power to operate so as to be practical for use at remote sites under adverse conditions such as a solar powered site. This implied a CMOS design throughout.

Implementation

During the course of our development, various different hardware prototypes were constructed and tested. Original experimentation focused on an Intel/Zilog architecture, and in fact prototype systems with conventional processors and DMA channels were built and tested for use in this application. Results of this approach were positive, producing systems capable of multiple channels of 56 kbps full duplex serial data, but insufficient for our design goals.

The breakthrough for this project came with the announcement by Motorola of their new MC68302 processor. This processor contains a 16/20 MHz 68000 processing core, and an additional RISC based communications processor (CP). The part contains 3 high speed serial channels and complete full duplex DMA support for those channels, allowing operation at baud rates well in excess of our stated megabit per second goal. In fact, the MC68302 can support bit clocking rates as high as 6 Megabits/sec within certain overall throughput constraints. The CP provides microcode to support five link level protocols including HDLC. Additionally this highly integrated processing platform provides several hardware timers. prioritizing interrupt controllers, dual port memory? etc. It is implemented in CMOS, so that it's power requirements are small (approximately 50 ma during full operation), and in it's lower power/standby modes the power requirements are miniscule. This single chip was designed to fill virtually all of our design goals and provides in a single highly integrated package both a powerful general purpose processing platform and a dedicated high performance communications processor.

The MC68302 processor then became the platform for the development of the PackeTen® switch. To provide local/console access we chose the venerable 85C30

SCC. This brought the total number of channels to five: 3 multi-megabit capable channels and 2 local access channels. To meet our 10 channel criteria required two MC68302's and two 85C30's.

During the initial design phases one of the factors taken into consideration was the need for modularity and expandability. Since a full-blown system would not be necessary in all applications, the system needed to be scalable to its application. "This factor prompted us to separate the 10 channel system into a 5 channel IBM PC compatible card and a 5 channel standalone with the unique capability to connect the standalone card to the PC card and thus meet our goal of a 10 channel packet switch. This capability would provide the network builder with the system he needs now as well as expandability for future network requirements. The result is a 5 channel PC system [main card). a 3 channel standalone (daughter card). and by combining the two systems a 10 channel PC system.

Each system can support from 128k to 1 Megabyte of EPROM. Our current version of KA9Q's SOS requires approximately 300k of code space, allowing ample room for expansion. Each system provides for up to 2 Megabytes of 0 wait state RAM allowing large systems sufficient buffer space to avoid data loss during network congestion.

Each processor has 2k of EEPROM for initial configuration storage. Typical information stored in EEPROM is as follows

1. IP Address.
2. Call sign.
3. Host name of node.
4. Default route.
5. Default attach command.
6. Site alias name.
7. System operator password.
8. Optional NOS command lines which can be saved in EEPROM. These command lines are used to store additional, site specific configuration parameters.

Another major part of the PackeTen® system is the 16-64k of tri-ported memory. With a 10 channel system all three processors can communicate with each other via inter-processor communications channels (IPC channels), which are attached just like any other type of communication channel in NOS. Utilizing this approach the PackeTen processors communicate with the host processor (PC) and with each other through virtual network connections or "IPC" shared memory " links ". When configured in this manner the PackeTen system becomes a networking co-processor offloading network traffic handling from the PC. This allows the PC to be used for other applications. while the PackeTen remains a fully functional IP switch node in the network. For example. traffic arriving on one of the daughter card's channels can be routed through an IPC "link" to the main card for transmission through one of' the main card's ports. Also note that while the example given here is for a "PC" version of the system. it also applies directlv to the "standalone" PackeTen system when configured as a **10** port remote packet switch.

Since the PackeTen svstem was intended to provide a reasonably long term solution to the digital networking problem. it was decided that the physical network interfaces should be configurable in order to accommodate possible future modem/radio interface standards. The chosen solution was to separate the physical link interfaces from the main processing platform. Immediate needs dictated that an RS-232 interface be provided to support existing TNC's and modems for the local access channels. and a TTL level interface for such modems as the WA4DSY radio/modem. Therefore a combination RS-232/TTL interface card was designed. In addition to simple level conversion functions. this card provides commercial grade features such as digital loopbacks on the links to provide for extensive diagnost ics, and individual programmable control lines for radio /modem control functions. Additional interface cards are currently under consideration for such standards as RS-422 and ECL interfaces.

Software

No discussion of the PackeTen® svstem would be complete without at least some mention of the software system which supports it. As mentioned previously, one of the problems with building good networks is the requirement for more sophisticated software systems. From the beginning, we intended to produce a complete digital networking solution, and we believed that the place to start was with the KA9Q TCP/IP NOS networking package. However, in order to take advantage of this system. much work had to be done to: 1) Port the software from an INTEL based platform to a Motorola 68k system, and 2) Develop the software necessary, to allow NOS to work in a standalone/diskless configuration (i.e. NOSINABOX). The culmination of this effort is what we affectionately refer to as NOS302. This package provides the user with a complete implementation of NOS in EPROM, which will allow the user to take advantage of the PackeTen hardware, and put that system into service todav. The list that follows provides insight into some of the changes neccessary to support a standalone NOS system.

- Support to provide traditional AX25 users with PAD functionalitv, and access to the IP network. This feature is provided in standard NOS through the "mailbox" feature, but required much rework in order to provide the PAD functions in a standalone/diskless environment. The PAD function was deemed extremely important in order to allow non-IP users access to the network facilities without the need for a PC running an IP implementation. By providing this function, the packet user with an off the shelf TNC can also use the network effectively.

- Comprehensive on board diagnostics.

- Non-volatile configuration memory support.

- IPC shared memory virtual “links” between processors.

- Improved data buffering/queueing mechanisms for high speed operation. “Scatter gather" transmit and receive buffer chaining.

- Interrupt driven software timers added to the kernel allowing precise timing for such driver functions as keyupjkevdown of transmitters without the use of polling loops which waste processing power.

- Synchronous drivers providing full/half-duplex. DMA support for external high speed HDLC modems. These drivers support full clocking options both internal and external for receive and transmit clocking.

- Asynchronous drivers for local terminal/TX communications. SLIP links, etc. DMA and interrupt driven configurations.

- Full support for all currently supported NOS protocols, including AX25, SLIP, SLFP, NETROM, NRS, etc.

Status

The results of the PackeTen® project have been quite good. Prototype system tests were completed early this year, with production grade systems consisting of 6 layer PC boards available now. These systems are supplied complete with software and are available through Grace Communications, Inc.

Current installations are in service in Youngstown, Ohio, as well as in and around Chicago, with others soon to come on-line in other states. The Chicago based systems-are being used to implement full-duplex 56 kb/s "cell" sites in the construction of a replacement network for our old 9600 baud backbones with excellent results.

Performance indications are also very positive, with systems demonstrating the ability to handle 6 links at 56 kbps, 2 links at 9600 and 2 links at 1200 with no degradation in throughput. Additionally, systems have been successfully tested with a 2 megabit/s links running full duplex.

Conclusions

The PackeTen project has provided a next generation platform for amateur networking in the Chicago area. While this platform undoubtablv has provided a major improvement in the state of our networking capabilities. it’s main contribution is in it’s ability to allow further development of network application systems. Specifically, by allowing developers to work with a more powerful hardware and software platform. they can begin to build the kinds of applications mentioned earlier in this paper, (including digitized voice, remote file access systems! conference bridges, etc.) with the knowledge that sufficient bandwidth should be available to make those systems practical.