AMATEUR PACKET NETWORK AGENDA

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Introduction

The American Radio Relay League (ARRL) is sponsoring this first international Amateur Radio Computer Networking Conference for several reasons. One is to recognize the innovative work that Canadian and U.S. amateurs have already done in packet radio. Another is *to* explore the possibilities of an integrated amateur packet network. Assuming that there is a consensus that a network can be developed, the third is to try to set up a framework for orderly growth.

This paper outlines my current thinking on some aspects of amateur packet radio networking. I have included a number of things that I believe should be considered at this conference and in the few months ahead.

Organization

In the past year, there has developed an informal group of packet radio leaders from different clubs. Fortunately, these individuals have been both advocates and doers. They have been in frequent touch with each other using various means of communication such as amateur radio, personal meetings, the mails and other methods. I'm speaking mainly of:

Stu Beal, VE3MWM	Hamilton, ON
Dave Borden, K8MMO	Sterling, VA
Larry Kayser; VE3QB	Ottawa, ON
Doug Lockhart, VE7APU	Vancouver, BC
Hank Magnuski, KA6M	San Francisco, CA

I would also like to be counted in this group. I'm sorry if I left anyone out who feels that he/she should have been included. The above list is meant to include the persons acting as gateways between their clubs and most of the others.

So far, this informal group has managed get the word around on new developments and has been able to move things along.

In any new enterprise, there is a tendency for someone to propose that the informal organization be replaced by a formal one. It is my feeling that this is a highly experimental and dynamic endeavor and that we shouldn't fix what's working.

Therefore, I suggest that we give at least tacit approval to this informal group and give them the ball on deciding when this leadership function needs to be formalized.

Our organizational energies should be focused, for the moment, on supporting the existing organizations. As an individual, you should see to it that your club attracts new members and helps them get on the air with packets. Virtually all the clubs are grossly underfunded and could use help raising money, The club newsletters need more capable writers on a variety of packet topics,, In addition, writers need to send top quality packet tutorials and technical articles to the ARRL publications *QST* and *QEX*.

Network Management Issues

Network architecture (structure, hierarchy, protocol, routing strategies) needs to be ironed out soon. The Network Architecture Seminar of this conference should help to move this subject along toward some type of agreement. I personally favor a two-tier system. At the lower level, there would be Local Area Networks (each with their own repeater), designed to fit the needs of the area. At the higher level, we would have a larger network (sometimes called an *internet*) which uses commonly agreed rules and can pass traffic via hf, satellite and terrestrial circuits. Also, I feel it essential to the network's growth that a new station (terminal or network node) be able to fire up without begging someone's permission.

Financing the network needs some fresh thinking. Undoubtedly, the local area networks will be financed locally as are the numerous Z-meter fm repeaters. However, the internet needs both local and network-wide financing. The latter category may include a number of the following possibilities:

- A network membership (users and supporters) fee on the order of $25 or more a year.

- A fund such as the ARRL Foundation to appeal to all radio and computer amateurs.

- Proposals for seed *money* to government and/or industry. There is a joint AMRAD/ARRL proposal calling for funding of 8 hf packet stations in its early stages of consideration by the U.S. Government.

Applications of the network need to be thrashed out, The Applications Seminar of this conference should stimulate some new thought. For one thing, I think that the network should develop a capability of handling third-party traffic. Serious consideration should be given *to* handling teletypewriter (TTY) traffic for the deaf. Barry Strassler will present a paper on this subject. I believe that handling of deaf TTY traffic is feasible via a special type of computerized bulletin board (CBBS) developed by AMRAD called HEX (Handicapped Educational Exchange) which speaks both

ASCII and Baudot/Murray codes. In fact, we need to talk about the possibilility of interconnecting with *all* CBBS's in North America. This carries with it the problems of getting the individualistic system operators to understand the need to comply with the internet standards. Perhaps the knottier problem is how to screen all traffic to eliminate commercial and other no-no traffic before it is transmitted over Amateur Radio.

Acronymics

Acronymics is a made-up word meaning playing around with acronyms. We need some agreed names to call things within the network. I was recently advised to leave this subject to discussion over beer and pizza. Ignoring that, here goes.

First, I propose that the overall network be called AMNET. The term should specifically apply to the internet and generally to the various Local Area Networks (LANs) connected to it. AMNET is meant to be an umbrella term.

The internet will be made up of three transmission (sometimes called transport) systems, as outlined below:

- The satellite net, fortunately, has already been given an acronym: AMICON, standing for AMSAT International COmputer Network. In the interest of symmetry, maybe we should make the other transmission system acronyms end in CON.

- The net of vhf/uhf packet repeaters along the countryside or terrain could be called TERRACON.

- The high-frequency net uses the ionsphere to skip long distances, so why not dub this SKIPCON?

It would seem natural to follow commercial practice and call the stations that change from one net or medium to another *gateways.* I'm proposing to call these gateways: SKYGATE for satellite gateways, TERRAGATE for vhf/uhf gateways, and SKIPGATE for hf gateways. The need for SKYGATEs and SKIPGATEs is fairly obvious. But there could be TERRAGATEs too where there is need to change frequencies, data rates and perhaps protocols.

I suggest that we leave the naming of the LANs to the local sponsors. It may also be necessary to name some *virtual networks* that people cook up within the network. Eventually, I'd like to see all these names (frequencies and other parameters) published in a directory by the ARRL. The time will come quite soon when we will need a packet radio directory which lists all network facilities as well as individual packet radio stations. To kick this off, AMRAD is offering to collect the information and organize it in a directory form. We already have a CBBS Directory which could be included.

Internet Standards

If the internet is to work it must have agreed standards. There must be agreement on a wide set of particulars including protocols, routing strategies, radio frequencies, etc. Yet we need to temper this with maximum flexibility. There are a number of fundamental issues to be addressed. For example, do we want to look for government seed money and configure the network so that it can handle government traffic in emergencies; e.g., use ARPA's Internet protocol? Perhaps the other issues can be better handled according to the medium used:

Vhf/uhf Terrestrial Net Standards

This net should consist of a number of single-frequency vhf/uhf repeaters, each with a capability of working neighboring repeaters on the same frequency. This can go on for an unlimited number of hops, or the chain can be broken by changing to another frequency. Propagationally, the 144, 220 or 420 MHz amateur bands would be acceptable. I am inclined to push the 220-MHz band because it is underutilized. Influencing the choice of frequencies may be the signaling speed permitted by the Federal Communications Commission in the U.S. Current Rules permit only 1200 baud at 144 and 220 MHz and 19.6 kilobaud at 420 MHz.

What speeds should we use? In packet communications it is necessary to have a high enough signaling speed to handle the volume of traffic without the network going critical and being tied up permanently with retries. That says, "the higher speed the better." But, raising speed means increasing bandwidth (all other things equal) which means higher transmitter power for an acceptable signal-to-noise ratio. Certainly, 1200 baud is not sufficient for such a net. 2400 and 4800 baud are not that much better. 9600 becomes marginally usable. From here, the American National Standards Institute (ANSI X3.36-1975) pegs the standard speeds at integral multiples of 8000 bits per second, so the next speeds are: 16, 24, 32, 40, 48, 56 kilobits, etc. ANSI shows 16 and 56 as "selected standard signaling rates" and recognizes 48 kilobits per second as a recognized standard for international transmission. Thus, it looks like the choice for the high end is either 48 or 56 kb/s. The low-end choice seems to be 16 kb/s. I was pushing 48 kb/s because of its international blessing by the CCITT, but I have learned that very few circuits have been implemented at that speed and that modems are extremely rare/expensive. I suggest that we look very closely at 56 kb/s as a proposed standard. That still gives us a modem problem to be solved by amateur ingenuity.

If we want to operate such speeds at 220 MHz, we will need to petition the FCC for a Rules change. Probably the best approach is to request a Special Temporary Authority (STA) as a first step. I believe that we want to ask for permission to use up to 56 kb/s in a portion of the 220-MHz band. You may have noted that the Canadians already have Department of Communications permission to use various bandwidths up to 100 kHz in the 220-MHz band. Unfortunately, there is no simple method of equating bandwidth to signaling speed because things change with different modulation schemes. There has been a tendency for hams to think of fsk for transmission of data because we are used to sending RTTY that way. The problem is that fsk gobbles up too much bandwidth. Phase-shift keying (psk) conserves bandwidth, particularly if we can use quadraphase psk. There is much work to do on designing practical modems for these data rates. Commercial (say 56 kb/s) modems are far outside our price range. I'd like to see someone look into the design feasibility of a qpsk modem operating at a 10.7-MHz carrier frequency for the internet repeaters.

As for where in the 220-MHz band we should put these repeaters, I circulated an informal letter on this subject in May of this year. If you wish to research this problem, you should look at the Canadian Amateur Bands,[1,2] U.S. Amateur Radio Frequency Allocations,[3] and the ARRL Vhf-Uhf Advisory Committee 220-225-MHz band plan.[4] Study of these references reveals that the 220.0-220.5 subband is not usable because FCC rules do not permit repeaters. The FCC permits repeaters above 220.5 MHz. Starting at 221.9 MHz there is a weak-signal guard band, EME (moonbounce), propagational beacons, weak-signal cw, calling frequency, general operations (cw/ssb), as well as fm repeaters and simplex channels to use up the higher part of the band, as outlined in the band plan. So, that narrows packet repeater operation down to the subband 220.5 to.221.9 MHz in the U.S. This applies only to the internet repeaters or possibly local area net repeaters which use data rates above 1200 baud (with FCC STA or rules change, of course). Local repeaters using 1200 baud could operate on fm voice repeater or simplex frequencies in the 144, 220 or 440-MHz bands.

The proposed 220. 5-221.9-MHz internet packet repeater subband needs to be broken down into channels. Here's my first cut; I'd welcome some comments:

a. Channelize on 100-kHz intervals, e.g., **220.6, 220.7,** etc. This will allow us to run up to 100 kHz bandwidth per channel. It will probably be necessary to keep two channels operating in the same area at least 400 kHz apart. Packet receivers may use fm broadcast 10.7-MHz i-f transformers because of their low cost. Although fm broadcast band channel spacing is every 200 kHz, it is not usual to have adjacent channels allocated in the same area.

b. As the arguments over whether to use simplex or duplex packet repeaters are not over, it might be prudent to look at the possibility of designating some duplex channels within the 220. 5-221. 9-MHz subband,, If the duplexer possibilities permit this, it would seem logical to have several duplex channels with inputs at one end and outputs at the other end of the subband. Then, the simplex packet channels could go in the middle:

Frequencies	Proposed Use
220.6/221.6	Packet repeater pair
220.7/221.7	"
220.8/221.8	"
220.9	Packet repeater simplex
221.0	"
221.1	"
221.2	"
221.3	"
221.4	"
221.5	"

There is an immediate need for a group of people to work o:n terrestrial vhf/uhf repeater standards and hardware design. Because of the scarcity of commercial 220-MHz equipment with up to 100 kHz bandwidths and quick turn-around time, it appears that most 220-MHz packet repeaters will be homebrewed. Doug Lockhart, VE7APU has circulated an informal paper which proposes certain design criteria. His basic idea is to come up with a single-board repeater that can be easily replicated across the continent. We need someone to undertake this design effort on a priority basis.

AMICON Standards

The focus of this work has been on the use of the data communications special service channel (L2) on the AMSAT Phase III satellite. There is already a committee in place headed by Hank Magnuski, KA6M. They have already drafted several generations of AMICON specifications which have been circulated to those directly involved.

Hf Standards

My concept is to have at least 8 hf gateways in the U.S., and about 6 in Canada. Within the bounds of ionospheric propagation, all should be able to talk directly to each other. If not, some can relay.

I would like to see the hf net run automatically, without human operators involved in sending and receiving packets. Computer control and digitally controllable rigs such as the ICOM IC-701/720 and the Collins KWM-380 permit this. A signal plan in software would provide the time slots with frequencies, antenna orientations and other information required for communications between the then-active stations.

Now, on to hf signaling speeds. Here is an area where we will. have to do some experimentation. The enemy is *multipath.* If you could always operate at the maximum usable frequency (muf) for the path, you could send at almost any speed because there would be only one path through the ionospheric layer. On the ham bands, it is not at all certain that you will be operating at or near the muf. Presently, the hf bands are allocated every octave, the exception being the 21-MHz band which falls between the 14- and 28-MHz bands. The addition of the new WARC bands at 10 and 18 MHz will help this situation for the longer paths. There remains an octave gap between the 3.5- and 7-MHz bands which will make it difficult for the shorter hf paths where multipath is a limiting factor. (It would be nice to have a frequency near 5 MHz that could be used by hams for packet operations.)

The worst-case situation on hf for multipath is in the vicinity of **100** km (near-vertical-incidence paths). Here, the maximum expected delay difference at frequencies below the muf could be about 8.5 ms, according to Salaman work on Multipath Reduction Factor (MRF). [5-6]

MRF or delay difference is manifested by a new bit and old bit overlapping each other. The question becomes one of how much overlap can be tolerated before the signal is no longer readable. I suppose that the answer has a good deal to do with the decision-making process used in the demodulator and signal-processing circuits. Common sense would seem to lead one to conclude that 50% overlap is about as much as a receiving system could put up with. Laport says that the signal is mutilated when the prominent delayed wave in the multipath group surpasses 20%.[7] I suspect that a better number is somewhere between these values.

Fig. 1 shows the maximum signaling rates in bauds as a function of path distance and operating frequency with respect to the muf. It is derived from Salaman's work. The conversion used to change delay in ms to bauds is based on a 50% overlap of code elements. If you wish to believe the more pessimistic 20%, then you can divide these rates by 2.5.

I suggest that we recognize 75, 150 and 300 baud rates as standard for hf packet operations. Also, we should begin experiments with 600 baud under an STA from the FCC in order to determine whether it should also become standard under a rules change. Initially, hf packet testing should use 75 baud to iron out the other bugs. Then, testing of higher speeds should proceed under valid test methods capable of sorting out multipath from inadequacies of demodulators, etc. Operationally, it makes sense to operate at the highest speed at the time, consistent with good copy. Assuming that we find the speed will vary under different path conditions, we should consider making the speed adaptive. By adaptive, I mean that signaling speed should be under software control so that the computers at each end can decide on which data rate is best for the prevailing conditions.

Multipath distortion is not the only problem facing us on hf. Other types of fading, other signals, man-made noise and natural noise all conspire to prevent us from sending perfect packets through the ionosphere. Hams will make a substantial

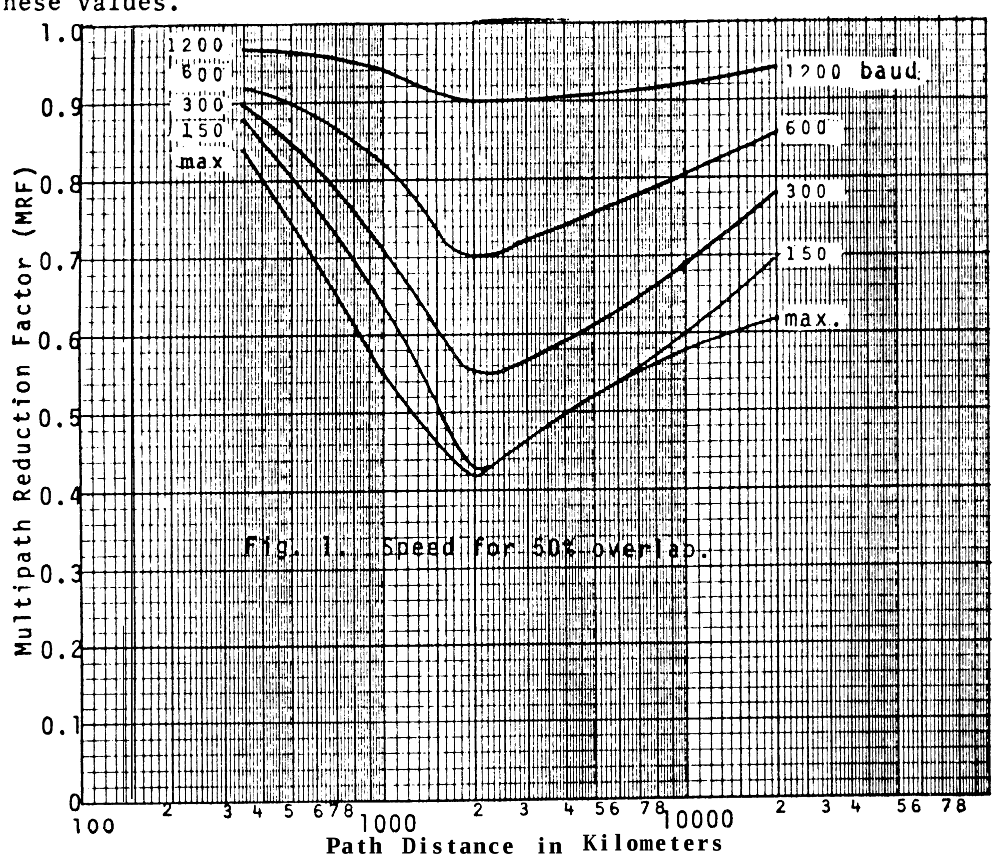

Fig. 1. Speed for 50% overlap.

contribution to technology if we can make this work reliably. Simply sending packets over an hf circuit will result in many retries (when conditions are not perfect). Nonetheless, some of that should be done in order to get a feel for the problem. However, it now looks very likely that we should use some type of forward error correction (FEC). An FEC system called AMTOR, based on CCIR Recommendation 476, is currently being tested overseas.[8] A small number of U.S. amateurs were granted an STA to experiment with AMTOR in November 1980 by the FCC.[9] Jerry Dijak, W9JD is currently developing an hf FEC system.[10,11] There remains much work to do, both theoretically and experimentally. There are some interesting questions. One is, why do we keep throwing out packets which have one or more errors in them? Is it practical to compare two or three pretty good copies of a packet in memory and make a perfect one?

We need some standard operating frequencies for hf packet communications. At this time, I believe that we need two frequencies per hf band -- one for network operations, one for direct use between individual stations (for experimentation, traffic handling, etc.).

In February, 1981, I mailed an hf packet frequency survey request to a number of individuals in locations covering North America. Unfortunately, the response was not what I had hoped. Rut, I wish to thank Bill, W4MIB and Pete, N5TP for the considerable number of hours that they monitored looking for activity on the RTTY bands. Their results, combined with mine, showed a fairly consistent bell-shaped curve within the RTTY segments. This led to the general conclusion that there were some good spots just inside the low and high ends of each RTTY subband. In addition to monitoring for on-the-air activity, research was done on published or other known usage.[12] Also taken into account were: U.S. F1 allocations,[3] Canadian F1 allocations,[2] the " onsiderate Operator% Frequency Guide,"[13] and the IARU Region 1 HF Band Plan.[14]

<u>80 Meters:</u>

3500- 3775 U.S. F1 allocation
3500- 3725 Canadian F1 allocation
3610- 3630 Considerate Opr's Freq. Guide
3580- 3620 IARU Region 1 HF Band Plan F1

Published or other known usage:

3580	W1AW cw bulletins & code practice
3583	Southwest CW Traffic Net
3585	Missouri CW Net
3587.5	Louisiana RTTY Net
3590	Empire Slow Speed Net
	Third Region Net
	Washington Section Net
3595	Georgia State Net
3596	Pine Tree Net
3598	Southern California Net
3600	Kentucky CW Traffic Net
	Kentucky Slow CW Traffic Net
3602	First Region Net
3605	Buckey Net RTTY
3610	Eastern Pennsylvania CW Net
	Kansas CW Section Net
	Pennsylvania Training and Tfc Net
3615	Louisiana Amateur Net
3617.5	Virginia Specialized Comm. Net
3620	AMSAT - RTTY Net
	Georgia Emergency RTTY Net
3625	W1AW RTTY Bulletins
3630	Kentucky RTTY Net
	Northern California Net
3633	New Hampshire Net
3635	Idaho Montana Net
	Tennessee CW Net
3637.5	RTTY Autostart

<u>40 Meters:</u>

7000- 7150 U.S. F1 allocation
7000- 7150 Canadian F1 allocation
7090- 7100 Considerate Opr's Freq. Guide
7035- 7045 IARU Region 1 HF Band Plan F1

Published or other known usage:

7040	Eastern Canada Net
	Hit & Bounce Net
7045	Ontario Southern Net
	IARU Region 1 HF Band Plan for SSTV
7090	Forty Meter Interstate RTTY Net
	Gater Net
7095	W1AW RTTY Bulletins

<u>20 Meters:</u>

14000-14200 U S F1 allocation
14000-14100 Canadian F1 allocation
14080-14100 Considerate Opr's Freq. Guide
14080-14100 IARU Region 1 HF Band Plan F1

Published or other known usage:

14075	RTTY autostart
14076.5	Canadian packet beacons
14080	W1AW bulletins & code practice
14082.5	Heath computers, autostart
14095	W1AW RTTY bulletins

<u>15 Meters:</u>

21000-21250 U.S. F1 allocation
21000-21100 Canadian F1 allocation
21090-21100 Considerate Opr's Freq. Guide
21080-21120 IARU Region 1 HF Band Plan F1

Published or other known usage:

21095	W1AW RTTY bulletins

<u>10 Meters:</u>

28000-28500 U S F1 allocation
28000-28100 Canadian F1 allocation
28090-28100 Considerate Opr's Freq. Guide
28050-28150 IARU Region 1 HF Band Plan F1

Published or other known usage:

28080	W1AW bulletins & code practice
28095	W1AW RTTY bulletins

After review of all information available, my recommendations for specific hf packet frequencies are:

Band	Direct	Network
80 meters	3612.5 kHz	3627.5 kHz
40 meters	7092.0 kHz	7098.0 kHz
40 meters R1*	7036.0 kHz	7044.0 kHz
20 meters	14076.5 kHz	14098.0 kHz
15 meters	21092.0 kHz	21098.0 kHz
10 meters	28092.0 kHz	28098.0 kHz

**R1 frequencies are for use in ITU Region I and for Transatlantic packet communications.*

Over the past few years, there has been a virtually complete phase-out of 850-Hz shift for hf fsk. The hf fsk standard is now 170 Hz. This has been somewhat of a mixed blessing. On the positive side, 170-Hz shift occupies less bandwidth thus conserving spectrum in that sense. However, at 850-Hz shift, there was considerable decorrelation of the mark and space frequencies. In other words, the mark and space frequencies were so far apart that they tended to fade independently. This opened up the possibility of processing these two signals as two separate diversity branches. Diversity combining could give equivalent gains of something on the order of 8 dB or so depending on a number of factors. In a way, this was moot because amateur RTTY demodulators did not take advantages of this decorrelation when 850-Hz shift was used. I bring this up because we have another shot at it. Clearly, 170-Hz shift is not what we need to run data rates such as 300 and (possibly) 600 baud. Bob Watson, a design engineer who is working with state-of-the-art demodulation techniques, has given this problem a great deal of thought. He is proposing that we go to 600-Hz shift. This does a number of good things. 600 Hz is wide enough that mark and space tend to be decorrelated most of the time. It permits keying speeds up to 600 baud. It would allow us to use synchronous transmission and reception. Frequency diversity and synchronous detection can provide considerable gain.

Local Area Net Standards

For the most part, LAN standards seem to be developing along the lines of 1200 baud, Bell 202 modems, 2-meter simplex repeaters, using the VADCG terminal node controller board for the individual station, etc. Much of this has to do with the availability of the VADCG TNC boards and quantities of Bell 202 modems. The 1200-baud data rate is also the highest speed presently authorized by the FCC for the 144 and 220 MHz bands.

Things don't necessarily have to stay in this same pattern. In fact, there will develop a number of reasons why we should try some different techniques. If speed is a problem at 144 and 220 MHz, of course we can move to 420 MHz where the FCC permits 19600 baud. Someone can make a pitch to the FCC to change their rules to allow higher data rates at 144 MHz and above. In fact, the ARRL has already done so under petition #3788. The availability of higher-speed surplus modems or an easily reproducible printed-circuit board designed by amateurs could make the higher-speed modem picture a bit brighter. A new board to replace the VADCG TNC could change things, possibly by reducing the cost. In other words, there is more than enough room to experiment.

My basic point is that we need some commonality to help local networks come about but need to encourage local experimentation and innovation.

Conclusion

I hope that the foregoing information and recommendations contribute to the thinking processes in the development of amateur packet radio networking. Please understand that nothing that I have presented is cast in concrete. We are all learning.

The time to design a packet network is now. Many of the people who will do the work are at this conference. We can muster the talent and resources needed to do the job.

I would like to thank the ARRL, National Bureau of Standards, AMRAD membership, AMSAT membership, the Bureau Radio Amateur Signal Society and numerous individuals who have made this conference possible.

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