Network Extension Unit (NXU)

Purpose--Bandwidth Capabilities

The purpose of the application note is to provide a description of the NXU bandwidth. The details will cover the following:

- General description
- Bandwidth capability

General description

The NXU is a general-purpose device that interfaces communication equipment by utilizing current network infrastructure. The NXU is considered to be an internet-focused application exploiting VOIP (voice over internet protocol) technology. The advantages to incorporating an NXU into existing communications architecture are:

- Enable low cost, extremely flexible radio communication networks
- Multiplex voice audio and data over a standard Ethernet network
- Eliminate the need for leased lines and microwave sites, to eliminate the requirement for pilot tones and other in band signaling
- Facilitate centralized communication from one computer

Bandwidth

What it Bandwidth?

Bandwidth is used to describe the transfer rate of data from one point to the next at any given time. Bandwidth is a key aspect of networking and the Internet business.

Bandwidth usage depends upon how equipment, in particular, the NXU, is programmed or configured to function, either, alone or as part of a group. When calculating bandwidth usage of the NXU, the programmer must consider TCP/IP overhead, duplex operations, voice compression settings and data settings. The NXU mainly uses a connectionless-oriented protocol called User Datagram Protocol (UDP) and, when utilizing the RS-232 serial data port, will make use of a connection-oriented protocol called Transmission Control Protocol (TCP). In order to understand how much bandwidth is being utilized by the NXU at any given time, as a consumer, you need to understand each element of the data flow process from end user to end user.

What is a TCP/IP header?

TCP/IP (Transmission Control Protocol/ Internet Protocol) header can be easily described as a system used to support network communications. A header is a bundle of relevant information in order to get the data from point to point. TCP/IP can be considered the disciplinary for how data is processed through the Internet and the single most important network protocol, without it, you would not be able to transfer or receive data.

TCP/IP is a two-layer program. The top layer, TCP, manages the assembly of messages to be transmitted and received over the Internet. The bottom layer, IP, places the origin and destination address on the packets of data. TCP/IP can be compared to sending a letter or package through the postal system. The package has to be boxed and taped with certain packaging material, the package must have a sender and receiver address, and it must be stamped and sealed by the postmaster for delivery. Once the package is sealed and stamped, the postal center coordinates

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and manages the delivery of the package from start to finish. This is essentially how TCP/IP headers work.

Within TCP/IP, there is a protocol that needs to decide how the information is going to get there, similar to the way the post office decides based on the delivery charge. UDP (User Datagram Protocol) is the protocol that is comparable to sending mail by air and TCP is the protocol comparable to sending registered mail by truck. UDP protocol allows the system to be more efficient, utilizing speed vs. fail-safe delivery. UDP is faster than TCP due to no error checking and flow control responsibilities called a checksum; thus, using less bandwidth than TCP. Additionally, UDP will not constantly ask for a confirmation that the package made it from sender to receiver; whereas, TCP will keep trying to deliver the package and continue requesting a confirmation of the delivery until the package is delivered or it simply times out. A great example of using UDP would be for voice applications, such as, VOIP (Voice Over Internet Protocol) and ROIP (Radio Over Internet Protocol).

TCP (Transmission Control Protocol), in essence, is the registered mail by truck, providing guaranteed end-to-end reliable delivery service. Included with TCP is an error checking and flow control process, which makes the TCP process slower than UDP process, utilizing much more bandwidth. ***TCP protocol is only used when using the RS-232 serial data port***. The RS 232 data port is not typically used; however, when it is used the NXU utilizes TCP protocol to conduct and ensure the data transfer from end to end. This application is typically used to send commands from one system to another. At any given time, the TCP data transfer will use 100% of the bandwidth and is dependant upon how much data is being acknowledged at the end user. In addition to TCP protocol, the RS-232 serial port requires a BAUD rate. BAUD is a measurement of the “signaling rate” which means how fast data is transmitted per second. BAUD rate is, for all intended purposes, the rate at which each data packet travels per second. So, if you have a BAUD rate of 300, then 300 data packets (signals) are transmitted per second. Signal events can be described as bits of information. **(NOTE: BAUD rate is not the same as *data rate*.)** Data rate is measured in bits per second. Baud port settings for the NXU are 300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200. Factory default setting is for 9600 baud.

Important Note: If the RS-232 is not being used then the bandwidth usage will follow UDP protocol rules. If the RS-232 is not being used then the TCP protocol is not being used and the bandwidth is at zero. Keep in mind that whatever application is being used, the information is sent in bursts not a constant stream of voice or data. For example, most VOIP/ROIP traffic during a one-minute period may have 2 to 3-second bursts of voice traffic or data at any given instance. When configuring the proper type of medium for applications using internet protocol, the consumer must consider worst-case scenario.

Checksum/ Flow Control

The IP Checksum is an additional part of the TCP/IP header. It is the error checking mechanism that is active while using the TCP protocol. This mechanism ensures the data that is being sent in packets gets to the destination. This is only available using TCP protocol. The UDP does not have checksum in place for the intent of utilizing speed vs. total deliverability. TCP checksum is 4 bits of the TCP/IP header, which is part of the NXU total bandwidth calculation during RS-232 applications.

Full Duplex vs. Half Duplex Operations

In the NXU, TCP/IP overhead of bandwidth is 20 to 25%, the actual bandwidth considers duplex configuration. The NXU allows for full or half duplex audio operations. Full duplex audio is when users can transmit and receive audio simultaneously. A telephone conversation is considered full duplex. Half duplex audio is only one user at a time can talk at any given instance. Most radio communications are half duplex capable.

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Vocoder Operation\Voice compression Method

A vocoder operation is the ability to convert human voice or sounds into a digital signal and recreated to sound like human sounds. Transmitting VOIP can consume a huge portion of the network bandwidth. A solution to effectively process VOIP requires converting voice information into digital signal processing algorithms in order to compress the voice information so that less bandwidth is consumed. Algorithms are best described as well-defined instructions to process information. As a rule of thumb, the more voice compression, the less bandwidth used, the less quality of voice output and vice versa, less voice compression, more bandwidth used, better quality of voice output. In the NXU, the options of voice compression at half or full duplex configurations is left up to the consumer.

The available voice compression settings are as follows:

Method 1 GSM--13 Kbps, suitable for voice communications only (not recommended for tone signaling). This method offers the greatest compression with reasonable voice quality. This is the default setting for the NXU.

Method 2 ADPCM--16Kbps, suitable for voice or tone signaling. This method offers good voice compression, but the voice quality is lower than other compression methods.

Method 3 ADPCM--24Kbps, suitable for voice or tone signaling. This method offers less compression than ADPCM 16Kbps, but the voice quality is better.

Method 4 ADPCM--32Kbps, suitable for voice or tone signaling. Offers even less than Method 3 compression, but the voice quality is the best of the ADPCM compression types.

Method 5 PCM--64Kbps, suitable for voice or tone signaling. Offers the highest quality of all compression methods, but provides the least compression. ***You should use this method only if your network offers low latency and throughput.***

Voice Compression\Tone Signaling

Another part of duplex, vocoder, and voice compression capability is tone signaling. There are many different types of tone signaling and the type used will directly determine which vocoder method will be best suited. Pure tones do not occur with human speech. The NXU offers some of these different voice compression methods to support a variety of applications; however, these methods do not fair well with tone signaling. Tone signaling is not a procedure that the vocoder was designed to handle. Vocoders were designed to operate on human speech. As a general rule, the lower the bit rate, the less likely a vocoder is to handle tones properly. Some examples of tone signaling are frequency shift keying (FSK), pilot tone, EIA key tone sequencing, and dual-tone multi-frequency (DTMF). A great advantage of using the NXU for tone signaling is that it incorporates the only known vocoder designed to operate with FSK data. Electronic Industries Alliance (EIA) key tone sequencing is a burst of high, low, and hold tones mixed with audio. The EIA key sequencing is used to key and control transmitters. A pilot tone is the simplest form of tone signaling. It is typically associated with COR applications in the voter and audio communication unit assets. It is a steady tone, which does not fluctuate in amplitude or frequency and indicates a radio is being squelched. Dual Tone Multi-Frequency is one of the most difficult keying methods because two tones are sent for a period of time in order for DTMF decoders to validate the two tones. In DTMF theory, the two tones are the ingredients that make a digit. In order to prevent interruption of the dual tone relationships, only the two highest methods of vocoder settings is recommended. In order to handle tone signaling, choosing the right vocoder method is key to successfully sending and receiving tones from the NXU. For some common tone signaling, it is recommended to use the following vocoder selections in order to ensure the tone is recognized by the NXU.

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Recommended usages for Tone Signaling:

Tone Type	**Vocoder Method**
Frequency Shift Key (FSK)	PCM 64Kbps Method 5 (Highest quality of all compression) or ADPCM 32Kbps Method 4 (ONLY if the FSK data rate is not too high)
Pilot Tone	Any ADPCM 16,24,32Kbps Method 2-4, or PCM 64Kbps Method 5
EIA Tone Key	PCM 64Kbps Method 5 (if you try to use 32kbps Method 4, it may work but is not recommended due to its specific keying requirements)
Dual Tone MultiFrequency	ADPCM 32Kbps Method 4 or PCM 64Kbps Method 5

"Keep Alive" Mechanism

A benefit of the NXU is its ability to default to a "keep alive" setting. When no audio is being transmitted, the unit will send a "keep alive" packet every four seconds to ensure the link is still open, essentially using little bandwidth.

What is the Bandwidth Formula?

The bandwidth formula consists of all the elements previously discussed in this application note. Keep in mind the protocol type, as well as, the type of duplex/vocoder method and the TCP/IP header baud rate.

Baud Rates	
300/1200/2400/4800/9600/19200/38400/57600/115200	
TCP Bandwidth Calculations for Half Duplex Operations	
Compression Setting	**Results: (vocoder rate (x) 1.25) + (baud rate (x) 2)= B/W**
13Kbps	16.25Kbps + (baud rate X 2) = bandwidth
16Kbps	20Kbps + (baud rate X 2) = bandwidth
24Kbps	30Kbps + (baud rate X 2) = bandwidth
32Kbps	40Kbps + (baud rate X 2) = bandwidth
64Kbps	80 Kbps + (baud rate X 2) = bandwidth

Baud Rates	
300/1200/2400/4800/9600/19200/38400/57600/115200	
TCP Bandwidth Calculations for Full Duplex Operations	
Compression Setting	**Results: (vocoder rate (x) 1.25) + (baud rate (x) 2)= B/W**
13Kbps	32.50Kbps + (baud rate X 2) = bandwidth.
16Kbps	40Kbps + (baud rate X 2) = bandwidth
24Kbps	60Kbps + (baud rate X 2) = bandwidth
32Kbps	80Kbps + (baud rate X 2) = bandwidth
64Kbps	160Kbps + (baud rate X 2) = bandwidth

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TCP Protocol Bandwidth formula: (vocoder rate (x) 1.25) + (baud rate (x) 2)= B/W

For example, if the consumer has programmed the NXU for full duplex with a voice compression setting set for method 5--128Kbps on the VOCODER (highest quality of voice or tone signaling), and the RS 232 data port is being used, you would calculate the bandwidth as follows:

(vocoder rate (x) 1.25) + (baud rate (x) 2)= B/W

Result: (**128 (x) 1.25 = 160 Kbps) + (10 (x) 2 = 20) =**

160 + 20 = 180 Kbps of bandwidth

The NXU will consume approximately **180Kbps** of bandwidth.

Another example would be if the consumer has programmed the NXU for half duplex with a voice compression setting for Method 4 ADPCM--32Kbps using the RS-232 data port, you would calculate the bandwidth as follows:

(vocoder rate (x) 1.25) + (baud rate (x) 2)= B/W

Result: (32 (x) 1.25= 40 Kbps) + (10 (x) 2= 20) =

40 + 20 = 60 Kbps of bandwidth

The NXU will consume approximately **60Kbps** of bandwidth.

UDP Bandwidth Calculations for Half Duplex Operations	
Compression Setting	Results: **(vocoder rate (x) 1.25)= B/W**
13Kbps	16.25Kbps
16Kbps	20Kbps
24Kbps	30Kbps
32Kbps	40Kbps
64Kbps	80kbps

UDP Bandwidth Calculations for Full Duplex Operations	
Compression Setting	Results: **(vocoder rate (x) 1.25)= B/W**
13Kbps	32.5Kbps
16Kbps	40Kbps
24Kbps	60Kbps
32Kbps	80Kbps
64Kbps	160Kbps

UDP Protocol Bandwidth formula: (vocoder rate (x) 1.25)= B/W

In the same scenario but without the RS-232, if the consumer has programmed the NXU for full duplex with a voice compression setting set for method 5-128Kbps on the VOCODER (highest quality of voice or tone signaling), you would calculate the bandwidth as follows:

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(vocoder rate (x) 1.25)= B/W

Result: 128 (x) 1.25 = 160 Kbps

The NXU will consume approximately **160Kbps** of bandwidth.

Another example would be if the consumer has programmed the NXU for half duplex with a voice compression setting for Method 4 ADPCM--32Kbps, you would calculate the bandwidth as follows:

(vocoder rate (x) 1.25)= B/W

Result: (32 (x) 1.25) = 40 Kbps
The NXU will consume approximately **40Kbps** of bandwidth.

References

Network Extension Unit (NXU) Installation and Operations Manual, Rev 3.1, May 2003

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