NXU-2 RoIP Link to Eliminate Voice-Grade Leased Line

Purpose

This Application Note will describe a method at which NXU-2 Network Extension Units can be utilized on an existing digital network to eliminate costly Voice-Grade Leased Lines.
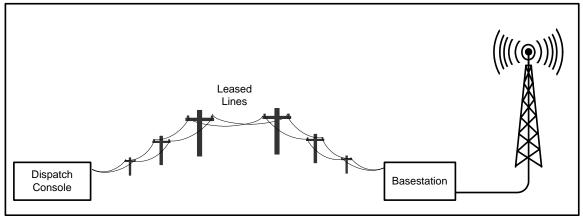
Introduction

Voice-Grade Leased Lines are regularly used in public safety land-mobile radios systems as dedicated baseband communication links between two remote points. Leased-Lines are also known as: Tie Lines, Wireline, Dedicated Line, Private Line, and Bell 3002, to name a few.

This symmetric telecommunications link, consisting of a 2-Wire or 4-Wire path, can tie a dispatch console to a basestation, for example, or provide connectivity between radios or drop repeaters separated by many miles. Unlike dialup voice-grade switched-circuit PSTN telephone lines, these leased lines provide 24-hour, full-period connectivity, and reliability by detouring traditional switch-circuits at the telephone central office (CO).

The following example is a typical leased-line dedicated link between a dispatch console and a remote basestation.

Leased-Line Link

Depending upon the service provider the end-user can expect a virtual point-to-point link that encompass microwave, copper, optical fiber, and even satellite links. In any case, whichever methods are used to facilitate this reliable connection, the link is transparent to the end-user.

Bell 3002 is a common provision for voice-grade leased-lines in public safety communications systems. Some of the specifications are as follows:

- 2-Wire or 4-Wire
- 600 Ω Impedance
- Audio Profile: 300- to 3000-Hz
- Frequency Shift: ± 5 Hz
- Control: Tone Only, no DC Control due to lack of hard wire

- Conditioning (depending upon the level of conditioning the specification can improve on frequency response, group delay and attenuation across the band. However, monthly reoccurring costs will increase with each level of conditioning):
    - C1 Conditioning or C2 Conditioning

However, there is a price to pay for these features and reliability.

In most cases Voice-Grade Leased Lines are installed and managed by telephone companies, up to the demarcation point of the end-users premises. As the end-user, you select the quality or grade of the dedicated line, and the method at which each terminal end point interfaces to the radio system.

Cost can be itemized as such:
- One Time Costs:
    - Initial System Provisioning Fee
    - Purchase of termination equipment between demarcation and radio system
- Recurring Costs:
    - Leasing of termination equipment between demarcation and radio system
    - Per Mile Costs Between End-Points based upon Grade of Service
    - Line Conditioning

Advantages of Lease Lines:
- 1:1 bandwidth ratio guarantee.
- 100% unshared access to stated capacity.
- Unambiguous link is relatively secure.

Disadvantages of Lease Lines:
- COST
    - Recurring monthly costs are based upon distance between each terminus. Cost is nearly proportional to distance. Cost figures can range between $400- to $1500- per month per line.
    - User must purchase and manage termination equipment between telephone company's demarcation and the private user's radio system.
    - User must pay for service even during low-capacity demands.
- Some telephone service providers are reducing the availability of voice-grade lines, and concentrating on the deployment of digital-grade leased-lines (T-Class, ISDN, etc).
- Inflexible link, cannot easily link to different or redundant end-point.

Requirement

Eliminate the monthly recurring cost of dedicated leased-lines, while retaining full-period connectivity and reliability of a leased-line.
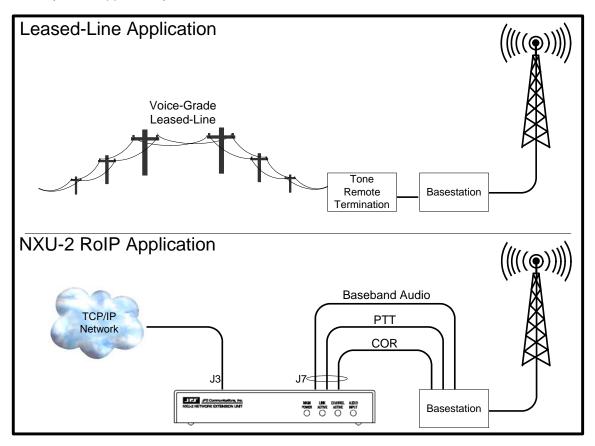
Solutions

Voice Grade Leased Lines can be circumvented by transporting digitized baseband audio from land-mobile radio systems over existing TCP/IP networks supported by NXU-2 Network Extension Units.

The JPS Communications NXU-2 Network Extension Unit is a standalone device that interfaces full-duplex baseband audio, (1) RS-232 port and (4) status bits onto a TCP/IP Ethernet network. The NXU-2 uses RoIP (Radio Over Internet Protocol) to convert land mobile radio baseband
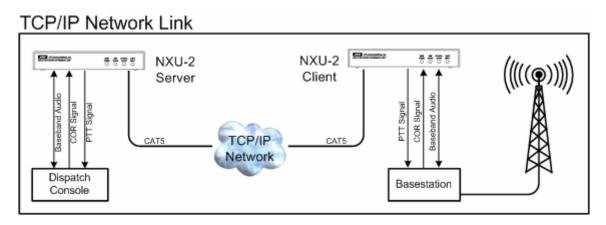
audio to datagram, which can then be routed over an existing digital network. The NXU-2 can also address the essential control signals used by land mobile radio systems. These control signals consist of the COR signal generated by a device when it is receiving a radio transmission, and the PTT signal which requests a device to begin a radio transmission. VoIP alone cannot handle these control signals, and that is why RoIP, used by JPS Communications, is essential to providing compatibility to land-mobile radio systems.

The following diagram illustrates an end-point supported by a leased-line application and the same system supported by an NXU-2 RoIP link.
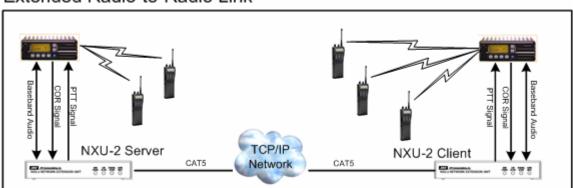

Two NXU-2's can be associated across a TCP/IP network by assigning one NXU-2 as a *Server*, and the other NXU-2 as a *Client*. The purpose the *Server NXU* is to wait on the network for a *Client NXU* to connect to it. The purpose of the *Client NXU* is to locate and connect to as specific *Server NXU* over the network. Once the association is established (typically within 5 seconds) RoIP traffic can commence in full duplex fashion.

TCP/IP Network Link

The previous example illustrates the original example of a typical leased line dedicated link between a dispatch console and a remote basestation, except (2) NXU-2 Network Extension Units linked together using an existing TCP/IP network are used at each endpoint to support the dispatch console and the basestation, thus eliminating the leased line.

In fact, the baseband audio of any land-mobile radio device can be linked over an Ethernet network using a pair of NXU-2's. The following is another example of an extended link between two spatially diverse sites using the same radio frequencies.

Extended Radio-to-Radio Link

When the mobile or portable LMR users in the field transmit to the Server radio (left), their program audio will be transmitted by the Client radio (right) at the far-end NXU-2 RoIP link. LMR users at both ends of the link will be able to 'virtually 'communicate with each other by utilizing the NXU-2 link created over the TCP/IP network.

Advantages of the NXU-2 Link:

- Virtual dedicated line, similar to leased line.
- Full Period, "Always ON" Connectivity.
- Minimal latency
- Little or no recurring costs if utilizing agency's existing network.
- Server / Client association is dynamic. User can associate to different assets as needed for diversity or redundancy.
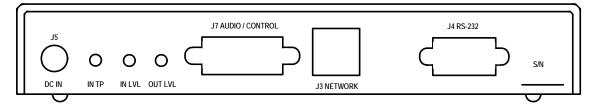
- DC Control or Tone Remote Control can be implemented. DC control is not possible with leased lines.

The NXU-2 has (3) primary connections:

- J3 – RJ45 TCP/IP Network Connection, 10 mb/s Ethernet. Able to connect back-to-back NXU-2's using CAT5 Cross Over cable, or over a segmented network using CAT5 Straight-Thru cables.

- J4 – RS-232, Asynchronous, Full Duplex. DB-9 connection used for serial programming of the NXU-2, as will as means of transmitting RS-232 data from one NXU-2 to another NXU-2 at a maximum user selectable baud rate of 115200 bps. This auxiliary RS-232 link can be used to control serial equipment over the network

- J7 – Audio / Control. DB-15 connection that will accept any JPS Communications supplied or end-user built radio interface cable. All baseband audio, COR and PTT control signals from the land-mobile radio device will interface to this connection.

NXU-2 Rear Panel Connectors

Any of the ACU® Radio Interface Cables manufactured by JPS Communications can be used to interface a radio to the NXU-2 unit. However, the supplied crossover adapter must be inserted between the NXU-2 J7 connector and the JPS Built Radio Interface Cable to "Crossover" the proper control signals. Naturally, the end-user can fabricate similar cables and connect the leads to the associated pin on connector J7, thus eliminating the need to use the Crossover Adapter.

J7 Connector Description

PIN	Signal	Description
1	Ground	Ground connection.
2		Not used.
3	/AUX In 0	Auxiliary Input 0 - Active low.
4	/AUX Out 0	Auxiliary Output 0 - Active low.
5	Ground	Ground connection.
6	Audio Input	Balanced audio input.
7	Analog Ground	Analog ground.
8	Audio Output	Unbalanced Audio output.
9		Not used.
10	/AUX In 1	Auxiliary Input 1 - Active low; general purpose.
11	/AUX Out 1	Auxiliary Output 1 - Active low; general purpose.
12	/COR Input	Input from radio COR, programmable active high or low.
13	/PTT Out	Output to radio PTT, active low, open drain.
14	Audio Input	Balanced audio input.

15	Analog Ground	Analog ground.

Although it is recommended that the input and output of the NXU-2 be balanced, the unit can accommodate single-ended connections by grounding one of the balance lead of the NXU to the audio ground. The COR and PTT control signal connections to and from the radio device is also accommodated by the J7 connector.
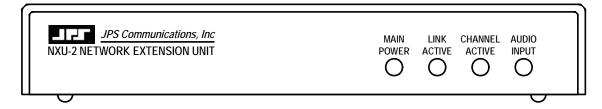
Network Configuration of NXU-2:

It is imperative that the network be configured such that the Server and Client NXU-2's have network visibility between themselves, otherwise the link will not be possible.

- ▪ Server NXU-2: This NXU must have a unique IP Address, and be configured as a SERVER.
- ▪ Client NXU-2: This NXU must also have a unique IP Address, and be configured as a CLIENT. Additionally, this client NXU must have the "Serve IP Address" field entered with the IP address of the Server NXU that it will be associating with.

If the devices are configured correctly the Link Active LED on each of the NXU-2's will be lit.

NXU-2 Front Panel LED's

Adjusting the Input Audio:

The audio input will accept signal levels from –30 to +11 dBm from the connected radio. Internal circuitry is used to amplify or attenuate this input as necessary to optimize the level. The signal level is adjusted by the IN LVL potentiometer accessible from the rear panel. The input is set to 0 dBm when shipped. Test point, TP1, is provided at the rear panel so the actual audio signal voltage applied to the A/D converter can be measured with an AC voltmeter. The correct level for best operation as measured at TP1 is about 0.2V or –12dBm (600 ohm reference).

If an AC voltmeter is not available, observe the AUDIO INPUT LED while programmed audio is present from the connected radio. The AUDIO INPUT LED should flash momentarily at each voice peak. Make appropriate adjustments using the IN LVL potentiometer.

Adjusting the Output Audio:

The audio output from the NXU-2 is a low impedance (10 ohm) unbalanced AC coupled output, which is to be routed to the radio through the interface cable. The output level is adjusted by the OUT LVL potentiometer accessible from the rear panel. This output provides a 0 dBm nominal level; +15 dBm clipping into a 600 ohm load. The audio output will supply signal levels from –30 to +11 dBm. Make adjustments necessary to properly modulate the connected radio.

COR Input Control Signal:

The COR input on J7 controls the RoIP data across the network. If a unit has an active COR input, that unit's audio input will be transferred across the network and will appear at the audio output on J7 at the other NXU-2 unit at the remote end. As long as the COR input of this NXU-2 remains active, the PTT output will remain active on the unit it's connected to. The audio channels are independent, and full duplex operation is possible. If the radio or other audio equipment does not have a COR output, it's possible to tie the NXU-2 COR input line to the active state so that data will be transmitted continuously.

VOCODER Selection:

The NXU-2 uses VOCODER algorithms to compress the baseband audio when it is converted to RoIP data. This will conserve network bandwidth. For example, some compression methods work well with voice and provide a high amount of compression, but do not handle signaling tones very well. Other methods handle tones and voice, but use more network bandwidth because they offer less compression. You may select the method from the following voice compression schemes that optimizes the trade-offs for your particular application. Note both NXU's in the link must use the same VOCODER:

1. GSM 13Kbps - Suitable for voice communications only. Should not be used if any tone signaling is required. Offers the greatest compression with reasonable voice quality. This is the default setting.
2. ADPCM 16Kbps – Suitable for voice or tone signaling. Offers good voice compression, but the voice quality is lower than the other compression methods.
3. ADPCM 24Kbps – Suitable for voice or tone signaling. Offers less compression than ADPCM 16Kbps but the voice quality is higher.
4. ADPCM 32Kbps – Suitable for voice or tone signaling. Offers still less compression, but the voice quality is the best of the ADPCM compression types.
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 good throughput.

Refer to the NXU-2 Installation and Operations Manual for further installation and operations information.

Conclusions

As packet switch networks that support TCP/IP protocol becoming more prevalent, and exceedingly more flexible, the full-time connectivity of Voice Grade Leased Lines used to support land mobile radio communications is becoming less attractive. Especially when the high cost of reoccurring expenditures associated with leased lines can be simply eliminated by using existing digital networks to transport audio in the form of VoIP or RoIP.

The JPS Communications NXU-2 Network Extension Unit was designed to address the audio and control signal characteristics of land-mobile radio devices, and provide a low maintenance solution to transport that audio over the Ethernet. When properly configured, back-to-back NXU-2's will provide equal, if not superior, full-period connectivity between remote radio devices. The Server / Client association of the NXU-2's will provide unsupervised connection management on an around-the-clock basis. Simple adjustments to the input and output audio levels to, and from the NXU-2 will provide unity gain, thus providing transparency to the radio system end-user.

Depending upon the monthly reoccurring costs of a single leased-line link, the break-even point of (2) NXU-2's will be realized within 2 to 4 months.

Acronyms

ADPCM: Adaptive Differential Pulse Code Modulation, is a form of Voice Coding and Decoding algorithm used by the NXU-2

COR: Carrier Operated Relay, is a signal from a receiver that indicates when a carrier or signal is being received and that the receiver is unsquelched.

GSM: Global System for Mobile Communications, is a form of Voice Coding and Decoding algorithm used by the NXU-2

ISDN: Integrated Services Digital Network, is a digital telephone connection that uses digital signals instead of analogue signals to handle the transfer of signaling and speech.

NXU: Network Extension Unit, is a device used to connect a DSP-1 module or a land mobile radio device over an IP-based network. The unit creates a network link that passes both voice and control signals in the form of RoIP.

PCM: Pulse Code Modulation, is a form of Voice Coding and Decoding algorithm used by the NXU-2

PSTN: Public Switch Telephone Network, which refers to the international telephone system based on copper wires and switched circuits for carrying analog voice data.

PTT: Push-to-Talk, A signal to a radio transmitter, which controls the actual transmission of radio frequency energy over the air.

RoIP: Radio over Internet Protocol, (compared to VoIP) not only converts voice to a digital format that can be sent over the Internet or other IP based network, but also convert PTT and COR control signals that are essential for seamless for radio interoperability. Also include are extra delay and jitter compensation.

TCP/IP: Transport Control Protocol / Internet Protocol, is an additional layer to the Internet Protocol, which ensures delivery of packets, sent across the network. It can handle situations such as lost packets or packets arriving out of order.

VOCODER: Voice Coder / Decoder, is an algorithm use by the NXU-2 that reduces speech signals to slowly varying signals transmittable over TCP/IP networks to conserve network bandwidth.

VoIP: Voice over Internet Protocol, is a method of sending voice communications across a digital network.

References

NXU-2 Installation and Operation Manual, JPS P/N 5000-600200, Revision 3.1, JPS Communications.