# Basestation Site Diversity Using the NXU

## Purpose

This Application Note will describe a method at which NXU Network Extension Units can be employed to provide communications backup in such cases where a primary remote controlled basestation becomes disabled due to natural or man-made disasters.

## Introduction

Basestations are devices that allow communications signals to be transmitted and received by a dispatch center or control station. Also known as the primary transceiver, a basestation can be located on mountaintops, tall buildings or strategically placed at communication towers to provide improved coverage in areas where obstructions, such as terrain, buildings or distance prevents reliable performance with users in the field, as well as supporting communications repeaters used in the system (see diagram below).



The illustration, above, depicts a remote controlled basestation linked to the dispatch control station using an NXU link, as opposed to using a more traditional link that relies on microwave or leased tie-line (see Application Note AN-3001-1, *NXU to Eliminate Leased Line*). In this case the NXU will convert analog audio to RoIP data, which is then transported between the sites using a TCP/IP network. With the NXU, control of the basestation can include DC, as well as inband transmitter keying tones.

In the example above, the remote basestation, which is positioned at a mountaintop site, does provide superior coverage, however such sites may have reliability issues that may include power failure, lightning strikes, fire, landslides, battery failure, or vandalism. Even remote basestations that are supported by towers located in low-lying areas can be susceptible to flooding or weather related disasters.

In many cases it would take several hours, or even many months to repair the remotely located basestation. This delay to re-establish communications would be unacceptable in a public safety environment (see diagram below).



## Requirement

To prevent a lapse in mission critical land mobile radio communications it is important to consider backup and redundant resources. This includes, backup batteries, uninterrupted power supplies, backup generators, spare electronic equipment cards and modules. But in the case of catastrophic natural or man-made disasters, communications officials should always consider redundant or backup basestations, a strategy known as *Site Diversity*.

## Solutions

*Site Diversity* has been in practice for many years in the form of receiver voters and comparators to enhance talk-in. Receiver diversity is achieved by strategically placing many receiver sites throughout the region to enhance the transmission coverage of lower-power radios in the field. Some of these voted systems might also utilize multiple or diverse transmitter sites to allow multicast or simulcast transmissions out to remotely located radios in the field. All are a form of *Site Diversity*.

A backup remote basestation site can also be defined as a Diverse Site. For instance, as mention previously, primary basestation sites are located to provide the best coverage to the users in the field, but these locations may not be ideal with respect to natural or man-made disasters. Communications officials may consider placing a backup basestation site on or near the dispatch center where the power source and the link between the control station and the backup basestation does not rely on service providers, tunnels, wireline, microwave links, power lines, etc, all of which can be compromised after a disaster (see Figure 1).

The building where the dispatch control station is located usually has backup lighting and power in the form of generators and batteries. The building should have a TCP/IP network, which should be viable even when the network backbone to the remainder of the local or state government has been debilitated. The building should also be outfitted with a redundant basestation, which does not necessarily have to be fully equipped with options, nor does it need to be as powerful as the primary basestation. The backup basestation performance should be adequate enough to provide some useful communications during a system failure or disaster.





Raytheon's NXU Network Extension Unit can be used to re-route audio between the dispatch control station and the failed remote basestation, to the backup basestation located in the same building, or for that matter, to any other functioning basestation within the system (see Figure 1).

Raytheon's NXU 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 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 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 Raytheon, is essential to providing compatibility to land-mobile radio systems.

Two NXUs can be associated across a TCP/IP network by assigning one NXU as a *Server*, and the other NXU 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 a specific *Server NXU* over the network. Once the association is established (typically within 5 seconds) RoIP traffic can commence in full duplex fashion (see diagram below).



Raytheon 5800 Departure Drive Raleigh, NC 27616 919.790.1011 http://www.raytheon.com The NXU has (3) primary connections:

- J3 RJ45 TCP/IP Network Connection, 10 mb/s Ethernet. Able to connect back-to-back NXUs 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, as well as means of transmitting RS-232 data from one NXU to another NXU 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 Raytheon supplied or enduser built radio interface cable. All baseband audio, COR and PTT control signals from the land-mobile radio device will interface to this connection.

#### **NXU Rear Panel Connectors**



Any of the ACU Radio Interface Cables manufactured by Raytheon can be used to interface a radio to the NXU unit. However, the supplied crossover adapter must be inserted between the NXU J7 connector and the Raytheon 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.

PIN	Signal	Description
1	Ground	Ground connection.
2		Not used.
3	/AUX In 0	Auxiliary Input 0 - Active Iow.
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.

## J7 Connector Description

Although it is recommended that the input and output of the NXU 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:

It is imperative that the network be configured such that the Server and Client NXUs have network visibility between themselves, otherwise the link will not be possible.

- Server NXU: This NXU must have a unique IP Address, and be configured as a SERVER.
- Client NXU: 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 NXUs will be lit.



## Figure 2: NXU Front Panel LED's

The network parameters of each NXU Network Extension Unit should be configured before hand to assure proper operations. There are several methods to modify the NXU parameters (Refer to the NXU Installation and Operations Manual for further installation and operations information):

1. <u>Serial Port Configuration</u> – This method requires the user to connect the serial COM port of a computer to the J4 RS232 connection on the NXU. Next, a console program such as

Hyper Terminal or Multi Thread TTY (supplied with the NXU) is used to enter typed command line instructions. This method is typically used when first provisioning the NXU.

- <u>Telnet</u> When an NXU and a computer are hosts on a common TCP/IP network one can launch a Command Console, and telnet directly to the NXU and use the same command line type instructions used in Method 1. One important aspect of Telnet is that the user must know the IP address of the NXU, and that the user's computer must have network connectivity in order for Telnet to be successful.
- Web Browser Configuration Utility When an NXU and a computer are hosts on a common TCP/IP network one can launch a web browser, and in the address bar of the browser, type and enter the IP address of an NXU. This will launch the Web Browser Configuration Utility of the NXU (see Figure 3).

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VoIP port:	1221	Command port:	23					
Server IP:	192 168 1 231	Server port:	1221					
Vocoder:	1. GSM 13Kbps 💌	Duplex mode:	Full 💌					
COR inhibit time (mS):	0 -	COR sense:	Low active (H/W)					
VOX hang time (mS):	500 💌	Client autoconnect:	Yes •					
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Serial port data bits:	8 -	Serial port parity:	None 💌					
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### Figure 3: NXU Configuration Utility – Configuration Page – Dispatch Site

When one NXU is configured as a SERVER and another is configured as a CLIENT they will be able to transport RoIP data between them if the network parameters of each are properly configure. The NXU configuration page of the Dispatch Control Station site, shown in Figure 3, indicates that this site is a CLIENT, and it is configured to connect to a Server NXU identified by the IP address of [192.168.1.231] indicated in the "Server IP" field.

Conversely, the NXU at the Primary Remote Basestation Site is configured as a SERVER, which means that it is eligible for a CLIENT NXU to link to it. If the IP address of the Primary Basestation Site is set to [192.168.1.231], then the system will have a viable RoIP link between the Dispatch Control Station NXU and the Primary Remote Basestation Site (see Figure 5).

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### Figure 4: NXU Configuration Utility – Configuration Page – Primary Basestation Site

The following diagram illustrates the NXU configurations for the primary RoIP link. Note the "Server IP Address" of the CLIENT parameters identifies which NXU SERVER on the network to associate to. In this is example; the RoIP link is established between the Dispatch Control Station Site and the "Day-to-Day" Primary Remote Basestation Site



## Figure 5: Dispatch Station with Primary Base Station

The following diagram illustrates the NXU configuration for the backup RoIP link. Note the "Server IP Address" in the CLIENT parameters has been changed to identify that it will link to the Backup NXU SERVER on the network.



Figure 6 shows the NXU Configuration Utility Configuration View of the Backup Site's NXU. Note that this NXU it its configured as a SERVER, and that it has the IP address of [192.168.1.232].



### Figure 6: NXU Configuration Utility – Configuration Page – Backup Basestation Site

### Switching Between Diverse Basestation Sites:

When the need arises to switch from the Primary Remote Basestation Site, to the Backup Basestation Site, as for instance after an earthquake, a communications official can easily commission the redundant link with a computer located on the network at the Dispatch Center. It is important to remember that the computer used to provision the NXU at the Dispatch Center must have network connectivity to the NXU at the Dispatch Center, at a minimum.

- <u>Use NXU Web Configuration Utility</u> Switch between the diverse basestation NXU can easily be performed directly within the NXU Web Configuration Utility.
  - Open the Web Configuration Browser of NXU CLIENT at the Dispatch Control Station by typing and entering the IP address of the NXU CLIENT.

• Click on the [Connection Management] link inside the Configuration screen (see below).

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- Click on [Disconnect] to disable the RoIP link to the failed Primary Remote Basestation Site.
- Change the existing IP address of the NXU supporting the failed Primary Remote Basestation Site [192.168.1.231], and enter the IP address of the NXU supporting the Backup Basestation Site, in this case [192.168.1.232].
- Click on [Connect] to associate CLIENT NXU at the Dispatch Control Station to the SERVER NXU at the Backup Basestation Site. The backup RoIP path should now be enabled.
- The user can easily switch back-and-forth between the two-basestation sites from this console (see Figure 7).



Figure 7: RoIP Link is Switched to the Backup Basestation Site

### 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 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 unit at the remote end. As long as the COR input of this NXU 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 COR input line to the active state so that data will be transmitted continuously.

### **VOCODER Selection:**

The NXU 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 NXUs 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 Installation and Operations Manual for further installation and operations information.

## Conclusions

Communications officials must always remain forward thinking with regards to backup communication systems and disasters, man-made or natural, which could disable mission critical land mobile radio communications. Even if the integrity of a remote site is fortified by utilizing battery backup, solar array backup, generators, security, and electronics equipment redundancy, a toppled communications tower could prove life threatening to the users in the field.

By positioning a backup Basestation Site at a location that is not dependent upon remote infrastructure, and that is sharing the same power and network infrastructure with the Dispatch Control Station, communications officials can easily provision this redundant asset in times of disaster.

Raytheon's NXU Network Extension Unit can provide a means to simply allow the Communications Official to re-provision RoIP links between the Primary Remote Basestation Site and the Backup Basestation Site, or for that matter, any other basestation site, when the remote assets become disabled.

## Acronyms

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

**Baud**: is a unit of measure for data transmission speed. 1-Baud is defined as one electronic state change per second. Also known as "Bit-Per-Second".

**CAT5**: An Ethernet cable standard that is the 5th generation of twisted pair Ethernet cabling and the most popular of all twisted pair cables used today.

**Client**: Client devices are provisioned to link to a specific Server devices over a TCP/IP network (see Server).

**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.

**GND**: Ground, is an electrical potential that is equivalent to zero volts.

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

**HyperTerminal**: HyperTerminal is a terminal emulation program that comes standard with all Windows OS, Windows 95 or later. It is used allow computers to communicate with other computers or other devices.

**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

**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.

**RS232**: Recommended Standard 232 is a specification for serial communications between a computer and modem, or computer to other device to be controlled.

**RXD**: Receive Data, is an RS-232 designation with respect to data flow.

**Server**: Server devices are provisioned to wait to link to a Client devices by having the Client devices associate to it over a TCP/IP network (see Server).

**Telnet**: An Internet communications protocol that enables a computer to function as a terminal working from a remote computer.

**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.

**TCP**: Transmission Control Protocol TCP enables two hosts to create a connection and exchange data. TCP guarantees delivery of data. See UDP.

**TXD**: Transmit Data, is an RS-232 designation with respect to data flow.

**UDP**: User Datagram Protocol is connectionless protocol that runs on top of IP networks. UDP provides minimal error recovery features, instead provides a direct method to forward datagrams over a network, and consuming minimal network bandwidth. See TCP

**VOCODER**: Voice Coder / Decoder, is an algorithm use by the NXU 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 Installation and Operation Manual, P/N 5000-600200, Revision 3.1, Raytheon.