NXDN® versus DMR

a comparison of protocols

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WHITE PAPER

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Executive Summary

The transition to digital radio in the land mobile market has been fraught with fits and starts, misinformation and downright confusion. The goal of this paper is to help make the right protocol decision by separating fact from fiction.

Camps have been established with one side saying that their digital offering is better than the other, while the other says theirs is. This is especially true of the markets outside of public safety where manufacturers fight for market share. While standards have been established by different bodies that cover protocols, that hasn't stopped proprietary features and operations from creeping in. This document is designed to help select the best protocol for the use case. With that said, one must realize that there is more than a single digital protocol in the market and there are some unique features and/or functions to particular offerings. There are three digital protocols that have been adopted for use in the market, including an additional one that is not currently found in the Americas.

Table 1

PROTOCOL	STANDARD	CHANNEL ACCESS	MANUFACTURER'S NAMES	TYPICAL USE CASE
P25	TIA	FDMA/TDMA	Motorola – Astro Harris – VIDA Airbus – VESTA EFJ – ATLAS Tait – Taitnet	Public Safety, Some Utilities
NXDN	NXDN Forum	FDMA	Icom – IDAS Kenwood – NEXEDGE	Business/Industrial, Utilities, Some Public Safety, Public Service, SMR
DMR	ETSI	TDMA	Motorola – MotoTRBO Hytera – XPT Simoco – Xd	Business/Industrial, Utilities, Some Public Safety, Public Service, SMR
dPMR	ETSI	FDMA		Unknown in North America

As Table 1 shows, there are a number of naming conventions used by various manufacturers although they typically have to do with their systems. They can cover subscriber units if so designated by the manufacturer or they may choose to use the protocol name such as DMR. Since our focus in this paper is to examine NXDN and DMR, we will concentrate only on the standard and any typical variations from the standard.

NXDN and DMR Standards

These two protocols are based on standards written by two different bodies.

The DMR Standard was developed by the European Telecommunications Standards Institute (ETSI).

The Standard is defined in four documents.

- **TS 102 361-1: the DMR air interface protocol**
- **TS 102 361-2: the DMR voice and generic services and facilities**
- **TS 102 361-3: the DMR data protocol**
- **TS 102 361-4: the DMR trunking protocol**

The NXDN Standard was developed by the NXDN Forum through a joint technical alliance between Icom Incorporated and JVCKENWOOD Corporation. The goal was to satisfy the FCC narrow banding mandate initially proposed in 2005 and completed in 2013. In February 2017, the NXDN Common Air Interface (CAI) was accepted by the International Telecommunications Union-Radiocommunications Sector (ITU-R). The NXDN Standard consists of the documents listed to the right on this page, available on the NXDN Forum web site (nxdn-forum.com).

TECHNICAL SPECIFICATIONS

PART 1: AIR INTERFACE

- Sub-part A Common Air Interface
- Sub-part B Basic Operation
- Sub-part C Trunking Procedures (Type-C)
- Sub-part D Security
- Sub-part E Common Air Interface (Type-D)
- Sub-part F Trunking Procedures (Type-D)

PART 2: CONFORMANCE TEST

- Sub-part A Transceiver Performance Test
- Sub-part B Common Air Interface Test
- Sub-part C Basic Operation Test
- Sub-part D Trunking Operation Test (Type-C)
- Sub-part E Trunking Operation Test (Type-D)

NXDN and DMR Standards *–continued*

Both NXDN and DMR protocols support conventional and trunking operations as defined in Table 2. Motorola and Hytera's implementations of the DMR standard vary somewhat from the standard in the areas of networked repeaters and trunking. This will be addressed later in this document.

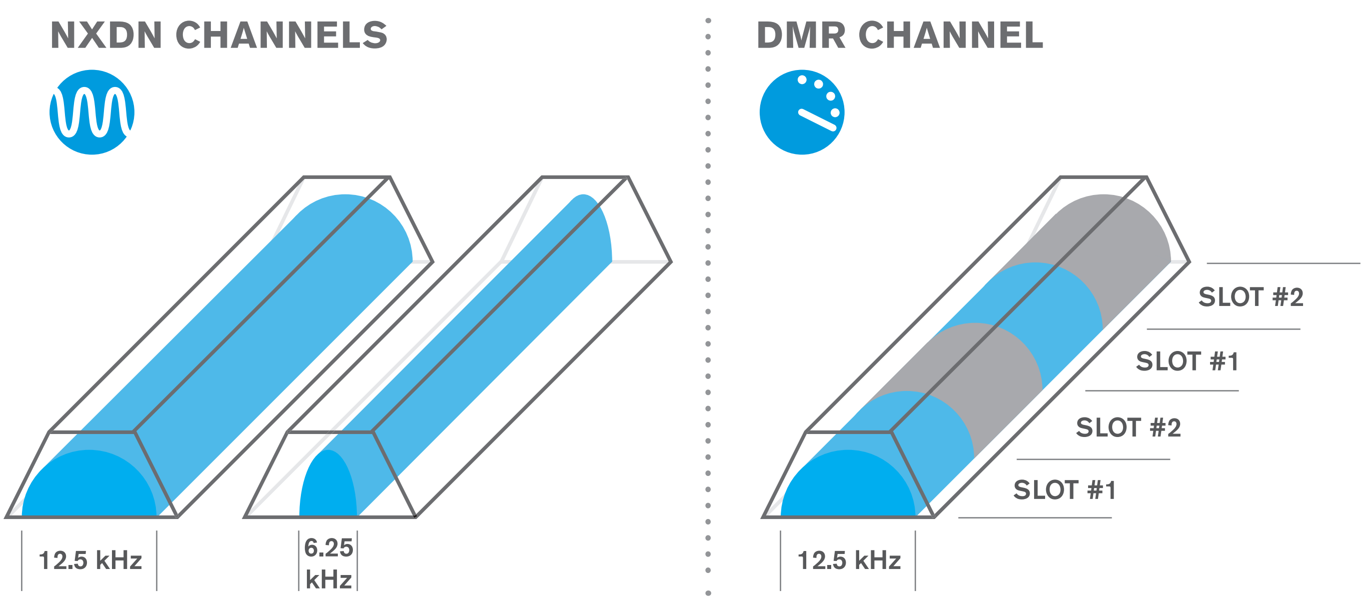
Table 2

NXDN	DMR	MOTOTRBO	COMMENTS
Conventional			
Direct (FDMA)	Direct (1-SLOT / 2-SLOT)	Direct (1-SLOT / 2-SLOT)	Simplex operation - single channel
Repeated	Repeated	Repeated	Half-duplex repeater operation
RX Voting	RX Voting	RX Voting	RX voting to fill poor talk-in areas
Networked			
Conventional	Tier II	IP Site Connect (manual)	Networked - requires user to change channels manually
Site Roaming	N/A (networked only)	IP Site Connect	Automatic roaming is not part of the ETSI standard for DMR.
Trunking			
Type-C (centralized)	Tier III	Capacity Max (Tier III)	Requires FB8 channels; continuous control channel operation
Type-D (distributed)	NA	Capacity Plus	LTR-like

NXDN and DMR Standards *–continued*

As with analog, both protocols provide solutions for simplex, repeated and trunking operations. The differences are in the channel access methodology and channel bandwidth. NXDN uses Frequency Division Multiple Access or FDMA and DMR uses Time Division Multiple Access or TDMA for their channel access methodologies. In FDMA, the channel is divided by frequency and TDMA divides the channel by time, as seen in Figure 1.

Figure 1



NXDN and DMR Standards *–continued*

NXDN allows a single carrier on a channel at a time and TDMA allows two carriers on a channel, but separated in time. Channel bandwidth use also varies between the two protocols.

NXDN operates on either a 12.5 kHz channel or a 6.25 kHz channel bandwidth.

NXDN operations
12.5 and 6.25 kHZ

DMR operations
12.5 kHZ

DMR supports operation on a 12.5 kHz channel only.

In the industry, the terms to describe these operational efficiency differences are 6.25 kHz operation and 6.25 kHz equivalency. DMR obtains efficiency with the use of two time slots on the channel compared to the actual 6.25 kHz occupied bandwidth of NXDN.

Both protocols use the DVSI AMBE+2™ vocoder for analog / digital and digital / analog conversion of voice. They vary in bit rate and FCC emission designation. These values are denoted in Table 3.

Table 3

PROTOCOL	CH. BW (kHz)	VOCODER BIT RATE	EMISSION DESIGNATOR		
			Voice	*Data*	*Voice & Data*
NXDN	12.5	7200 bps	8K30F1E	8K30FD	8K30F7W
	6.25	3600 bps	4KF00F1E	4KF00F1E	4K00F1W
DMR	12.5	3600 bps	7K60FXE	7K60FXD	7K60FXE

A Basic DMR Overview

DMR equipment is available in three tiers but only two tiers are sold in North America.

These tiers are:

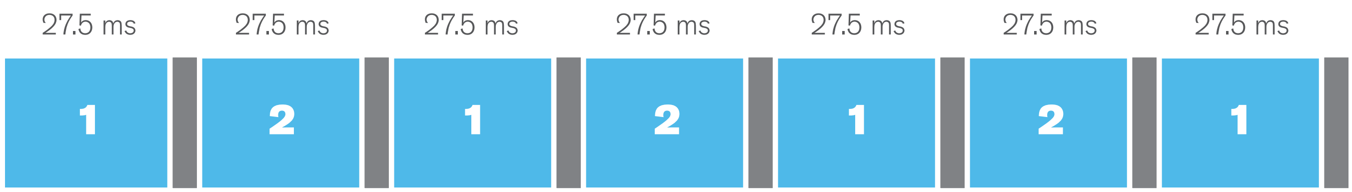
TIER I	TIER II	TIER III
Digital PMR446	**Peer-to-Peer** and **Repeater Mode**	**Trunked Operation**

Tier I is similar to the United States Unlicensed Family Radio Service Radios (FRS) in Europe. This frequency band is occupied by the amateur radio service in most of the Americas. Tier II and Tier III are the predominant tiers in the U.S. There are variations offered by several of the manufacturers but these are not pure to the DMR standard.

Both Tier II and Tier III employ TDMA technology, allowing for two time slots on a single 12.5 kHz channel. Over the air, the slot structure is 30 ms (27.5 ms slot + 2.5 ms guard) with a 50% duty cycle. The user of a slot transmits for 30 ms while the receiving radio, listens during that 30 ms window. Another transmitter and receiver may use the other 30 ms block of the second slot to communicate. This results in what appears to be simultaneous operation to users.

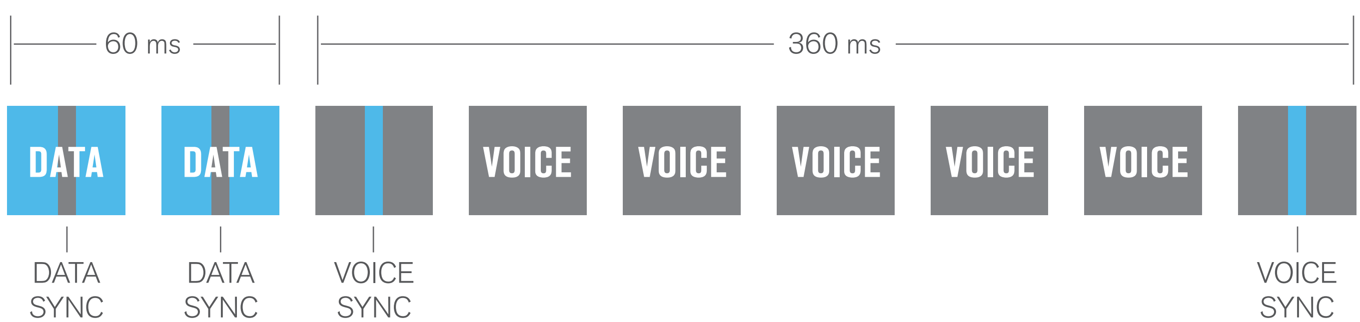
Figure 2 is a representation of the time slot cycle.

Figure 2



Since time slotting is used, synchronization is required to ensure that radios transmit and receive traffic only in their designated time slot. Different sync patterns are used between voice and data bursts so a receiver can differentiate between the two. To deal with co-channel interference, different patterns are also used for inbound and outbound channels.

Figure 3



Like analog, there are equivalent signaling features available in DMR. In DMR, Color Code is the equivalent for CTCSS and DCS.

A Basic DMR Overview *–continued*

Talk Groups and Unit IDs are available for users to separate units on a time slot, to identify a calling radio, and to provide different calling functions such as group and individual calling, and messaging. The Tier II services defined by the ETSI specifications are shown in Table 4. These functions are described in detail in ETSI TR 102 298, Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Digital Mobile Radio (DMR) General Design, Section 6.1 DMR Services Overview.

Table 4

SERVICES		SUPPLEMENTARY SERVICES	USE CASE
VOICE	Individual Call	Late Entry	Join in-progress call
		OVCM Call	Monitor Calls - Supervisor
		Talking Part Identification	PTT-ID
	Group Call	Late Entry	Join in-progress call
		Unaddressed Call	All Call type operation
		OVCM Call	Monitor Calls - Supervisor
		Talking Part Identification	PTT-ID
CONFIRMED PACKET DATA PROTOCOL	IP over PDP	None	NA
	Short Data over PDP - Status / Pre-coded		
	Short Data over PDP - Raw Data		
	Short Data over PDP - Defined Data		
UNCONFIRMED PACKET DATA PROTOCOL	IP over PDP	None	NA
	Short Data over PDP - Raw Data		
	Short Data over PDP - Defined Data		

DMR Tier II

DMR Tier II supports, as noted in the previous section, direct mode, repeated, repeated with receiver voting, and networked repeated.

Direct mode is single RF channel simplex between two units. There are two different types available. The original version was a single time slot used for communications between two units. A newer method allows for two time slots to be used on the channel. Like repeater operation, synchronization is required, but two different operational groups may share the same simplex channel, thereby increasing the efficiency of the channel.

Repeater operation in DMR Tier II is no different than analog repeater operation except for the availability of two time slots. This allows a single repeater to act as two repeaters although the same channel pair is used. The receiver voting allows additional receive only sites to be configured to fill problem areas of coverage, with the best receiver used as the input to the main site repeater.

In Tier II, repeaters may be networked to allow a user to communicate across multiple sites to increase coverage footprint. This is generally referenced as RF multi-cast. This is accomplished via IP connection between each site. The ETSI standard covers only a single site, therefore each manufacturer has developed their specific site connection methodology using IP. This may preclude radios from operating on a different manufacturer's Tier II multi-site repeater system without prior knowledge to implement the other system's method.

DMR Tier III

The Tier III standard feature set is defined by the following services:

GENERIC SERVICES	VOICE SERVICES	DATA SERVICES
• Mobile Station (MS) Access Control and Management using a control channel and a random access protocol • MS location with the system radio coverage by radio site identification and registration • Control Channel hunting • System acquisition authorization • Unified data transport mechanism; support short data services, supplementary data service and destination addressing through gateways • Broadcast of system parameters to MS • MS Authentication	• MS talk group call service • MS individual call service • All-Call service • Broadcast voice call service • Open voice channel mode call service (OVCM)	• Short Data service • Packet Data service • Supplementary data transfer service • MS stun and revive • MS kill

The Tier III services defined by the ETSI specifications are shown in Table 8. These functions are described in detail in ETSI TR 102 298, Electromagnetic compatibility and Radio Spectrum Matters (ERM); Digital Mobile Radio (DMR) General Design, Section 8 Trunking (DMR Tier III.)

DMR Tier III *–continued*

Trunked operation is supported in DMR Tier III. Tier III uses a centralized trunking method with a control channel that regulates access and assigns traffic channels on a site. Traffic channels are time slots available. Both single-site and multi-site systems can be deployed depending on the needs of the customer. Subscribers may roam between sites as needed in a multi-site system. As seen in Figure 4, the time slots are defined as logical channel numbers.

If Slot #1 of Repeater #1 is defined as a control channel, then Channels #2 through #4 may be used as traffic channels.

Like other centralized trunking systems, subscriber units monitor the control channel when idle. If a talk group becomes active and the subscriber is a member of that talk group, all subscribers who are a member of that group will get a go-to message with a traffic channel assignment.

Figure 4

DMR Tier III *–continued*

Table 5

SERVICES		SUPPLEMENTARY SERVICES	USE CASE
VOICE	Initiate Random Access Group Call	Late Entry	Join in-progress call
		All Call	
		Broadcast Call	
		OVCM Call	Monitor Calls - Supervisor
		Unaddressed Call	
		Call to Line PABX / PSTN	
		Priority Call	
		Emergency Call	
	Initiate Random Access Individual Call	Late Entry	
		OACSU	
		OVCM Call	
		Call to Line PABX / PSTN	
		Priority Call	
		Emergency Call	
	Initiate Press and Talk Individual and Group Call	By Random Access	
CONTROL (CSBK or MBC)	Broadcast System Parameters		
SHORT DATA	Status Message	Paging (one-way)	
	Individual Short Data Message		
	Group Short Data Message		
CONFIRMED DATA	Individual Packet Data Call - Connection Oriented		
	Individual Packet Data Call - Connectionless		
	Individual Circuit Data Call - Reliable		
UNCONFIRMED DATA	Individual Packet Data Call - Connectionless		
	Group Packet Data Call - Connectionless		
	Individual Circuit Data Call - Unreliable		
	Group Circuit Data Data Call - Unreliable		
UNCONFIRMED DATA	Individual Packet Data Call - Connectionless		
	Group Packet Data Call - Connectionless		
	Individual Circuit Data Call - Unreliable		
	Group Circuit Data Data Call - Unreliable		
VOICE	Group Call	Increase priority in Emergency	
	Individual Call		
DATA		Increase priority in Emergency	

A Basic NXDN Overview

NXDN equipment is offered for Conventional and Trunking operation. All NXDN configurations are available worldwide since no unlicensed version is offered in any market.

Conventional and Trunking operations may be broken down as follows.

CONVENTIONAL OPERATION	TRUNKING OPERATION
• Conventional Simplex • Conventional Repeated	• Type-C Trunking (Centralized) • Type-D Trunking (Decentralized)

Unlike DMR, NXDN is not broken down into tiers, so for the purpose of this paper, we will examine conventional and trunking.

In conventional, NXDN can be operated using analog methodology. A user may operate in simplex or use a repeater. Channel occupancy, again, is like conventional. A single carrier operates on a given channel, thus it is defined as single channel per carrier (SCPC) or in trunking, as FDMA. Only a single user may transmit on the channel at a time for intelligibility to be maintained. Both DMR and NXDN are subject to the same effects of FM capture since both are FM.

A Basic NXDN Overview *–continued*

NXDN is unique in that it can use either 12.5 kHz channel bandwidths or 6.25 kHz channel bandwidths. This is generally referred to as narrow and very narrow operation. When occupying these different channel bandwidths, the vocoder bit rate differs, therefore the emission designators differ as shown in Table 3. In addition, the data payload of signaling and voice or data have different frame lengths. In one frame at 12.5 kHz it is 40 ms in length and at 6.25 kHz, a single frame is 80 ms.

At the start of a transmission, the preamble is appended with a frame sync word to insure receiver initial synchronization capture. The sync is the same whether voice or data.

NXDN is unique
in that it can use either
12.5 kHz
CHANNEL BANDWIDTHS
or
6.25 kHz
CHANNEL BANDWIDTHS

NXDN can be used for voice, data or voice and data.

A Basic NXDN Overview *–continued*

Figure 4 shows the basic structures for very narrow and narrow.

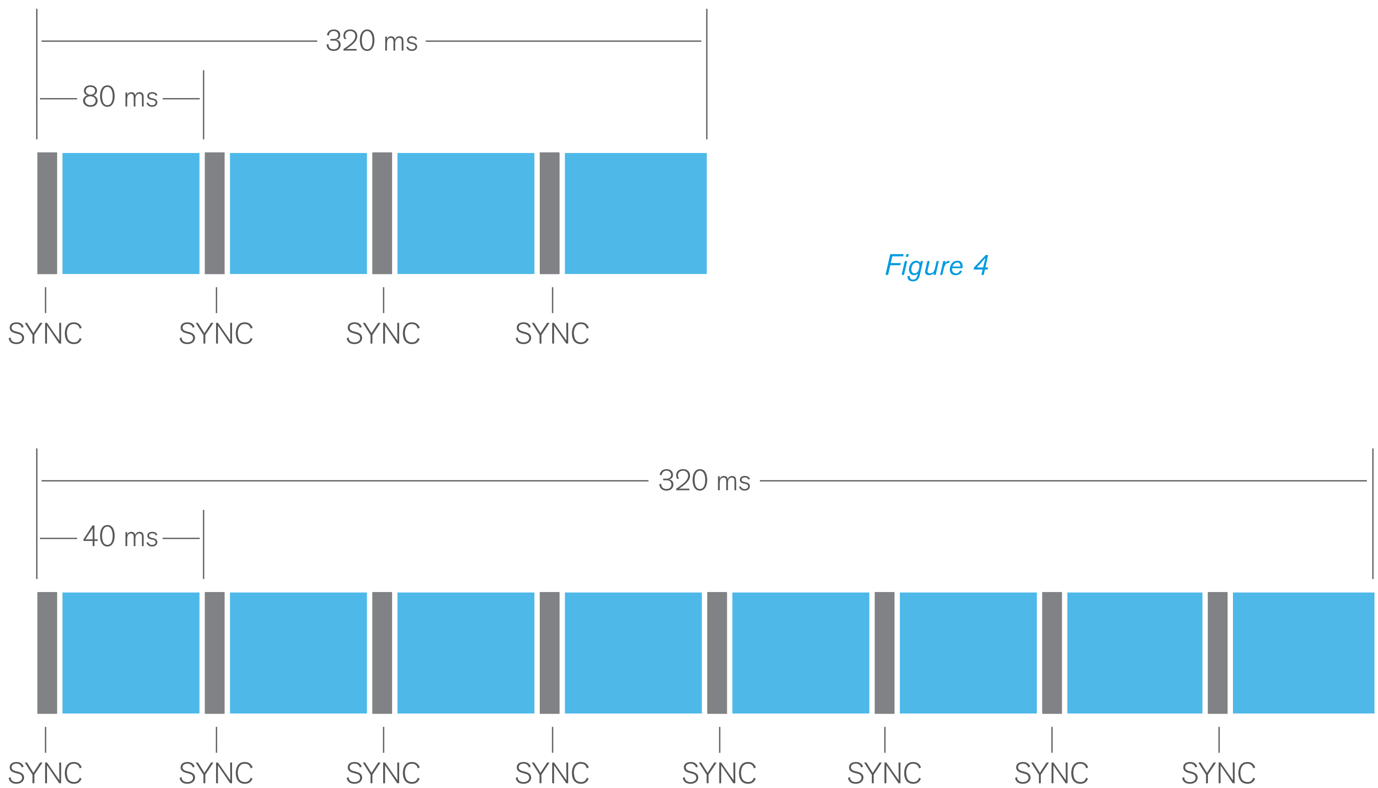


Figure 4

Although NXDN is digital, it uses signaling methods like analog. RAN (Radio Access Number) is used as an equivalent for CTCSS and DCS. Talk Groups and Unit IDs are available to separate units on a channel, identify calling radios and provide different calling functions such as group and individual calling and messaging. The NXDN TS 1-A Version 1.4, NXDN Technical Specification, Part 1: Air Interface, Sub-part A: Common Air Interface, Section 2.2 Functions Defined by CAI details the services available in both Trunking and Conventional Operation as shown in the Table 6.

A Basic NXDN Overview *–continued*

Table 6

SERVICE		TRUNKED		CONVENTIONAL	
		Multi-Site	***Single Site***	***Repeater***	***Direct***
VOICE	Broadcast Group Call	✔	✔	NA	NA
	Conference Group Call	✔	✔	✔	✔
	Individual Call	✔	✔	✔	✔
	Interconnect Call	✔	✔	✔	NA
DATA	Data Call	✔	✔	✔	✔
	Broadcast Data Call	✔	✔	✔	✔
	Short Data Call	✔	✔	NA	NA
	Broadcast Short Data Call	✔	✔	NA	NA
	Simultaneous Data Call	✔	✔	✔	✔
SUPPLEMENTARY	Status Call	✔	✔	✔	✔
	Broadcast Status Call	✔	✔	✔	✔
	Paging	✔	✔	✔	✔
	Emergency Call	✔	✔	✔	✔
	Emergency Alert	✔	✔	✔	✔
	Remote Monitor	✔	✔	✔	✔
	Remote Stun	✔	✔	✔	✔
	Late Entry	✔	✔	✔	✔
SYSTEM	Registration	✔	✔	NA	NA
	Group Registration	✔	NA	NA	NA
	Site Roaming	✔	✔	NA	NA
	System Roaming	✔	✔	NA	NA
	Composite Control Channel	✔	✔	NA	NA
	Restriction Control	✔	✔	NA	NA
	Fail Soft	✔	✔	NA	NA
	Call Queuing	✔	✔	NA	NA
	Priority Monitor	✔	✔	NA	NA
	Intermittent Operation	✔	✔	NA	NA
	Traffic Timer	✔	✔	NA	NA
SECURITY	Authentication	✔	✔	✔	✔
	Encryption	✔	✔	✔	✔

A Basic NXDN Overview *–continued*

In conventional mode, the subscriber operates almost identical to a standard analog push-to-talk, release-to-listen operation. It operates differently in that the audio is encoded and decoded into digital via a vocoder. The transmitter may occupy a single channel of a bandwidth of either 12.5 kHz or 6.25 kHz. The over-the-air data rate varies based on the channel bandwidth selected by the end-user. These figures are noted in Table 3.

As part of conventional mode, the subscriber unit can be operated in direct mode, simplex unit-to-unit or repeated mode via a repeater to extend range. RAN codes and talk groups may be used to segregate users in either type of operation. Repeaters may be networked via IP to allow extended functionality as follows:

- **Conventional Repeated with Receiver Voting**
- **Conventional IP Networked**
- **Conventional IP Networked with Site Roaming**

While the NXDN standard covers the common air interface (CAI) for the subscriber and repeater operation, the standard does not define the structure of the IP backhaul. Each system manufacturer uses their own structure, therefore repeaters of one manufacturer cannot be networked with those of another manufacturer.

NXDN and Trunking

The NXDN standard supports two different trunking protocols, Type-C and Type-D. The CAI differs between trunking and conventional. This adds a level of security since a conventionally programmed radio will not decode trunking traffic. Like conventional, trunking can be used on either 12.5 kHz or 6.25 kHz channels although channel bandwidth may not be mixed in a system.

Type-C uses a dedicated control channel that continually transmits. The system may be installed as a single site or multi-sites can be installed that allow subscribers to roam when leaving the coverage of a site. This increases the operational footprint of the user compared to that of a single site. The control channel manages registration of the subscribers as well as channel resources, assigning users to open channels upon request and directing a like talk group to that channel. This does not differ from the basic Tier III DMR trunking operation except that, in NXDN, channels are physical channels and not time slots on a channel.

Type-D operates in a similar fashion to analog LTR. Control is distributed between the repeaters and a home channel is assigned for a subscriber. Available only as a single site, but with a familiar operation, easing the migration path from LTR for the user.

Protocol Comparison

This paper has provided a basic foundation of NXDN and DMR. To properly compare the two protocols features and functionalities one must also provide information on those that vary somewhat from the basic standard. As discussed there are several manufacturers for both protocols. This section will include the various differences and also show where those differences are found.

Table 7 shows the basic conventional, networked and trunking operational modes as defined in the Standards or added as proprietary by a manufacturer. In general, the Standards cover only basic conventional and trunking operations. Manufacturers have added networking, therefore, as previously discussed, infrastructure cannot be mixed, although subscriber units may be mixed depending on what control signaling is used.

A manufacturer may provide a standards based system but add extended capability that only their subscribers can use, while another subscriber can still use the same system, without access to the proprietary feature.

Protocol Comparison *–continued*

Table 7

OPERATIONAL MODE	NXDN			DMR		
	NXDN Standard	**NEXEDGE (Kenwood)**	**IDAS (ICOM)**	**DMR Standard**	**MotoTRBO**	**Hytera**
CONVENTIONAL	Direct 6.25 / 12.5 kHz	Direct 6.25 / 12.5 kHz	Direct 6.25 kHz	Direct 1-SLOT / 2-SLOT	Direct 1-SLOT / 2-SLOT	Direct 1-SLOT / 2-SLOT
	Repeated 6.25 / 12.5 kHz	Repeated 6.25 / 12.5 kHz	Repeated 6.25 kHz	Repeated Tier II	Repeated Tier II	Repeated Tier II
	NA	RX Voting 6.25 / 12.5 kHz	RX Voting 6.25 kHz	NA	RX Voting	NA
NETWORKED	NA	IP Connected Manual	IP Connected Manual	NA	IP Site Connect Manual	IP Connected
	NA	IP Connected Site Roaming	IP Connected Site Roaming	NA	IP Site Connect Roaming	IP Connected Roaming
TRUNKING	Type-C Centralized	Type-C 6.25 / 12.5 kHz	Type-C 6.25 kHz	Tier III	Capacity Max Tier III	Trunking Lite/Pro Tier III
	Type-D Distributed	Type-D 6.25 kHz	Type-D 6.25 kHz	NA	Capacity Plus	eXtended Pseudo Trunk

Looking at the NXDN features, one can see that receiver voting and IP connectivity between conventional repeater sites has been added by the manufacturer. Since receiver voting is an infrastructure based feature, it is not subscriber unit centric, therefore any NXDN subscriber unit will be capable of operating. This also holds true of IP connected sites with manual roaming or what is referred to as selector roaming, which is when the user changes to that site's channel. IP connected with site roaming requires that the subscriber be programmed such that it can roam without user prompting.

As for trunking within NXDN, a subscriber with the proper programming and trunking type may operate on any manufacturers system per the Standard. There are no special variants between manufacturers to make the operation proprietary. Again, networking between sites even in trunking will vary, which means repeaters cannot be mixed and matched among manufacturers.

Protocol Comparison *–continued*

Within DMR, there appears to be more variation from the Standard. However, the Standard like NXDN covers direct, repeated and trunking. It does not cover networking of sites or receiver voting. Receiver voting is a non-issue since this is infrastructure based, so we may rule out any effects from it. Where issues arise is with networked and trunking operations. Each manufacturer has their particular "spin" on that operation. If we look at simple IP connected repeaters where the user manually roams, then there isn't an issue. IP connected with roaming introduces variables that require firmware and software tailored to ensure proper operation.

While there is a single trunking type in DMR, several manufacturers have developed their own version in addition to Tier III. These versions correlate with NXDN Type-D. Motorola has Capacity Plus and Hytera has eXtended Pseudo Trunk. Each uses a different methodology for assigning traffic channels in a multi-channel system.

Capacity Plus can be single or multi-site. Single site operation uses what it is termed a Rest Channel. Idle radios occupy an assigned Rest Channel until a call goes active. The call goes active on the Rest Channel which becomes the traffic channel and all radios not involved in a call move to a new Rest Channel or an open idle channel. At the end of a call, the system broadcasts the status of all channels. In multi-site operation, logical channels are defined as local or wide area. The local channel is repeated at the site where the wide area goes over the system. The trunking process is the same as the single site.

Hytera's eXtended Pseudo Trunk (XPT) is similar in operation to Capacity Plus as a single site trunking system. Subscribers are assigned a home repeater where they reside when idle. If the home repeater is available for traffic, it will use the pre-assigned repeater and time slot for communications. If not available, it will switch to an available channel based on the system status broadcast. This operation is very much like analog LTR.

Tier III and Type-C differ only in what is defined as a channel. Tier III defines a channel as a timeslot and NXDN defines a channel as a physical channel.

DMR Tier III and NXDN Type-C both use a control channel like many of the legacy public safety trunking systems. These systems can be either single or multi-site based on the user's needs. The subscribers reside on the control channel when idle and use the control channel for registration and channel requests. Tier III and Type-C differ only in what is defined as a channel. Tier III defines a channel as a time slot and NXDN defines a channel as a physical channel.

Both NXDN and DMR have defined encryption methodologies as part of their Standard. DES and AES are universal for both protocols where the basic encryption differs. Table 8 shows the encryption methods employed.

Table 8

NXDN	DMR	MOTOTRBO	HYTERA
Voice Security (Encryption)			
Basic (15 bit)	ARC4 (40 bit)	Basic (16 bit)	ARC4 (40 bit)
DES (56 bit)	DES (56 bit)	ADP (RC4 based)	AES (128 bit)
AES (256 bit)	AES (256 bit)	AES (256 bit)	AES (256 bit)

Protocol Comparison *–continued*

Other areas of differences between the protocols are within the available Unit ID (UID) and Talk Group (GID) range along with the signaling value range. As shown in Table 13, DMR has a significant number of UIDs and GIDs. While the range may be large, the system deployed may not support the maximum number of ID's available. The system purchaser must ensure that the system will support their requirements. This will vary from manufacturer to manufacturer especially when considering non-standards based systems.

Table 9

NXDN	DMR
Unit ID Range (UID)	
1 to 65519	1 to 16,776,415
Group ID Range (GID)	
1 to 65519	1 to 16,776,415
Signaling Value Range	
RAN = None, 1 to 63	Color Code = 0 to 15

REVIEW

The above paragraphs have summarized features and system types, the fundamental difference between DMR and NXDN is channel access. This has been discussed in previous sections; let's take a moment to review.

DMR is capable, by the use of time slotting, to have two users occupy a single channel in a pseudo simultaneous fashion. NXDN allows only a single carrier on a channel. It cannot share the channel with another user in a pseudo simultaneous fashion. It is a single carrier per channel. Both have their advantages and disadvantages when using this channel access methodology, plus the protocol itself limits operation. Where one protocol may work for a one user's system, the other may not and vice versa. The next section will deal with these items.

Faults and Foibles

We started off by stressing that these are complementary products and not competitive products. The reason for this statement is that one protocol may work better than the other for a particular use case. Let's look and discover where the proverbial wheels come off one, compared to the other.

There are probably many more examples than these, but these are the "big" ones that become obvious when selecting a protocol to use. This section should be read as a whole and not as a way to pick one protocol over the other. In the use case section, we will bring everything together.

One of the most obvious items, which is brought up often, is that DMR provides a two-to-one (2-to-1) advantage. This occurs on a 12.5 kHz narrow channel and is referred to as 6.25 kHz equivalent. NXDN can occupy a 12.5 kHz or 6.25 kHz (very narrow) channel. NXDN meets the true 6.25 kHz operation in very narrow and DMR is an equivalent. NXDN is true to the analog method of channel access, thus, the user sees no difference in migration whether on the subscriber or infrastructure side. Signaling is set in a similar manner as analog but instead of CTCSS or DCS, RAN is used. In DMR, there is a Color Code and a Slot that needs to be set for each subscriber which is not difficult but different for users migrating but does require an extra step.

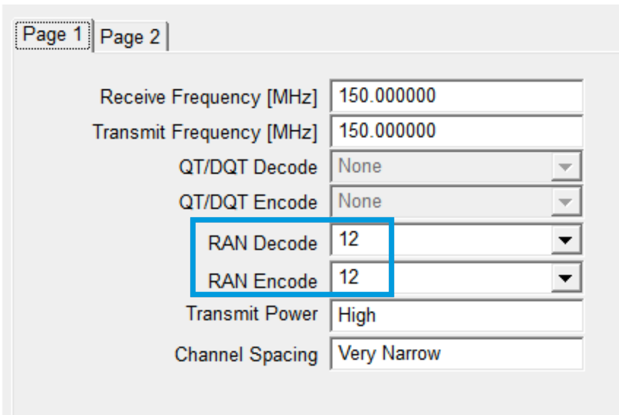
NXDN true operation
6.25 kHZ

DMR equivalent
6.25 kHZ

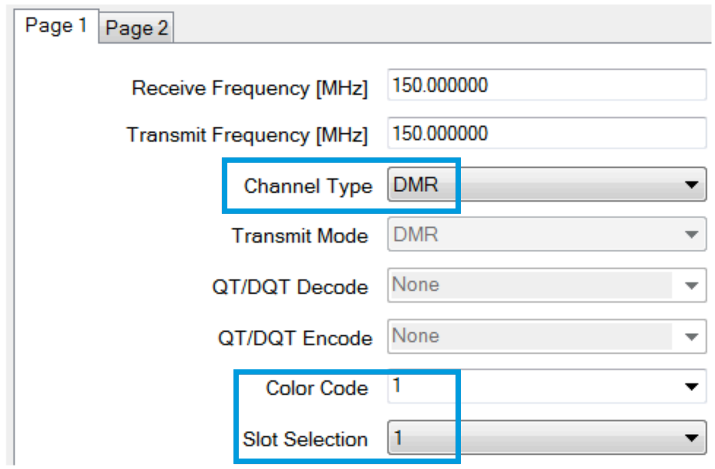
Faults and Foibles *–continued*

Figure 4

NXDN



DMR



To maintain decode in each protocol, the subscriber's receiver and repeater's receiver must obtain sync with the incoming frames. This is accomplished using a sync word that is repeated. In the basic overview of each protocol, a representation of each frame is shown for both protocols. DMR sends its sync mid-frame separated by 60 ms in two data frames and within the beginning and end of the voice frames. Since two time slots may occupy a single channel, synchronization is extremely important so a receiver may properly align in time with the assigned slot. Decode cannot start until sync is established.

NXDN has a sync word at the beginning of each frame so the decoder has a 40 to 80 ms window to obtain sync after joining an on-going call. In reality, at least three frames are needed before the decoder starts the decode process.

Once sync is established, the DSP can buffer a number of frames. This buffering allows it to properly replicate the original voice frame and send it to the vocoder. This number varies between protocols therefore late entry is affected differently between them. Late entry is defined by the period of time that it takes for a radio joining an in-process call to audio decode. DMR takes a minimum of 360 ms to enter into a call. NXDN varies due to the channel bandwidth available. For a NXDN Narrow channel, 12.5 kHz, it takes a minimum of 160 ms and for NXDN very narrow, 6.25 kHz, it can take between 320 and 560 ms.

Since the release of digital protocols for land mobile radio, we have seen the curve showing the difference between analog and digital. Digital with the use of forward error correction (FEC) yields an increase in range of approximately 20% but is this consistent between the protocols? NXDN demonstrates a conservative range increase of 20% compared to analog when subscriber and repeaters are properly installed and tuned.

NXDN demonstrates a conservative range increase of 20% compared to analog.

Since FDMA has been introduced, the single channel per carrier, the guard frequency that provides isolation between the channel and adjacent, have to be considered. If a user decreases his occupied bandwidth by using very narrow spacing, more isolation is provided from the adjacent channel and even on-channel signals. This improvement in signal-to-noise contributes to the receiver's ability to decode a lower signal strength. If a protocol uses a standard bandwidth, then no advantage is seen from improved signal-to-noise. With DMR, we have to consider not only guard frequency band but time between the slots.

Faults and Foibles *–continued*

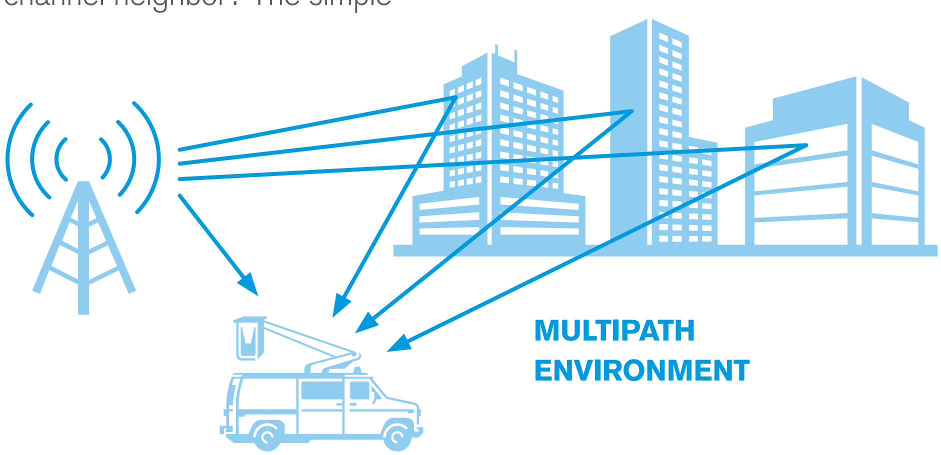
In DMR, there is a guard between slots of 2.5 ms. If our signal is delayed it can start encroaching on this guard time thus decoding will be halted so as not to create interference with the other slot. This is what has been described as the Near / Far effect. Extra time is needed for a distant unit to transmit back to, say, a base station compared to a unit that is near the base station. The distant signal, due to its delay, may encroach on the near unit when it starts to transmit on the other time slot. This limitation alone reduces the available footprint of a DMR system compared to a NXDN system. Studies done in the past on TETRA (TDMA) and Tetrapol (FDMA) demonstrated a three-to-one difference in coverage. One manufacturer notes that the Near / Far effect is less of an issue in an urban environment but in a rural area, the effect could be significant. A NXDN system will require fewer sites.

In RF, we must deal with what is referred to as multi-path. This is when a signal arrives at a receiver via two or more paths. The signals may arrive at the same time or be delayed one from another. They may also differ in relative amplitude due to path loss. The best example in the analog television days is what we called ghosting and in modern digital TVs where we see locked or dropped pixels or even full image lock-up.

Faults and Foibles *–continued*

If the path delay is small compared to the digital symbol time, then the effect may be constructive. If the delay is large, then it may be destructive, depending on the amplitude of the delayed signal. In digital, the BER would increase unless the delay is large enough to be subtractive on the signal thus cancelling the primary path. Since DMR is switching at a 2.5 ms rate between slots, path delay will be of great importance to maintain a low BER. DMR (TDMA) functions better when the signal strength is large to take advantage of capture where NXDN (FDMA) can decode at a lower signal strength in a multipath environment since it does not have to deal with signal switching which may contribute to the delay.

One general question that comes up is whether digital is a good co-channel or adjacent channel neighbor? The simple answer is no, if the channel is shared with an analog signal or the immediate adjacent is analog. While the signal strength falls off by one divided by range squared, the roar of a digital signal when received by a co-channel analog subscriber without signaling is quite annoying. If the signal captures the analog receiver, then it will block the front end thus reducing sensitivity. The same holds true for an adjacent channel. It takes less signal strength on the adjacent that is digital to block an analog receiver. Since DMR is switching between slots every 27.5 ms at 50% duty, it can create audio anomalies that will false analog CTCSS signaling. Care must be exercised in sharing a channel between a digital and analog system. The current contours seem to be insufficient at VHF based on actual field experience.



MULTIPATH ENVIRONMENT

Faults and Foibles *–continued*

While telephone interconnect has been basically replaced by cellular telephones, there are still areas where no cell coverage is available creating demand for telephone interconnect. As in analog, NXDN is capable of interconnect but operating in a half-duplex fashion. Due to the use of time slots, DMR is capable of operating full-duplex. This allows a radio user to carry on a telephone conversation like they would via a POTS line. No additional equipment is required to do this. NXDN could replicate this operation in a similar fashion, but it would require the splitting of both transmit and receive channels at a site to do this.

As it can be seen in this section, both protocols have their own advantages and disadvantages. How you intend to use the technology will dictate the protocol that best suits the application. The key is to study the usage and evaluate the standard protocol features before looking at the features offered by any system manufacturer. The key is not to be wooed by a non-standard feature that will drive you as a purchaser to obtain a system that doesn't fit how you need to use the system. It is important to investigate both the protocol and the manufacturer.

Basic Use Cases

The conclusion of the previous section recommended evaluating the protocol based on how it will be used. The last paragraphs will look at a few of these cases. Again, one must remember that these are not competitive products. The intention is to pick the best protocol for the application, so let's look at a few.

Let's consider a four-building complex where the current user has been using analog from a single conventional repeater. Since there are four buildings, the customer would like to provide four talk groups to split up the appropriate maintenance personnel. Based on prior discussions about the NXDN Type-D solution, what is considered best for the application? To look at this appropriately, we can break down issues as follows:

CHANNELS AVAILABLE	LOCATION	PREVIOUS OPERATION	USER GROUPING
Four FB6s	Urban office building; indoor coverage	Analog, single repeater that covers the complex	Four groups required

Basic Use Cases *–continued*

At first glance, we could easily satisfy this with trunking, but cost and complexity is higher. Talk groups can be used in conventional digital so one doesn't need trunking. Since the analog only system provided adequate coverage throughout the four buildings, our site placement is simple. We can either use four NXDN repeaters to give them four talk paths for the desired groups or two DMR repeaters for the four groups with expansion to four more groups as their capacity requirements grow. Based on helping the customer future proof for expansion and the current coverage of analog, conventional DMR is the best solution.

In the next case, a moderately sized rural county requires extended mobile and portable coverage where analog suffered in the past. They have a primary site and no other site is available. Their requirements breakdown as follows:

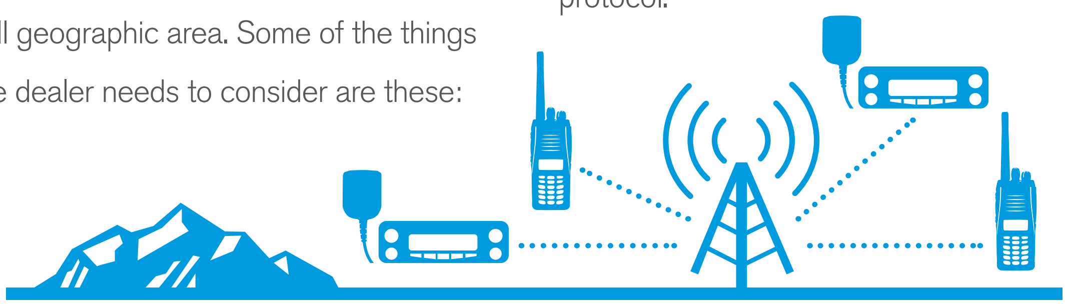
CHANNELS AVAILABLE	LOCATION	PREVIOUS OPERATION	USER GROUPING
One (1) conventional	Rural	Analog, single repeater with some voting; poor coverage	Less than 10 users per shift; central dispatch

Basic Use Cases *–continued*

Initially, a DMR conventional would increase capacity for the county, but they do not need the capacity. What they need is overall coverage in the fringe areas from a single site. They need a good talk-in profile to the repeater so that a weak digital signal can be decoded. They need to make sure their communication is reliable even on late entry so there is minimal delay in the transition from mobile to portable. This county would be best served by NXDN conventional.

The final example is that of a dealer that wants to provide radio as a service on an SMR system. The dealer may need to provide reliable communications to his subscribers over a large or small geographic area. Some of the things that the dealer needs to consider are these:

The protocol answer is not as simple as the other two examples. While the above questions are few, there are many other questions that these lead to that will help the dealer select the right protocol. The dealer must look carefully at what he is trying to accomplish and the cost of implementation. If the dealer is replacing a small analog system and wants to add subscribers, then DMR may fit his requirements. If he plans to build-out a large rural system, then NXDN would be a better protocol choice. There is no right or wrong protocol choice in this case, but it is critical that the dealer weighs his requirements against the capability of the protocol.



CHANNELS AVAILABLE	LOCATION	PREVIOUS OPERATION	USER GROUPING
What do I currently have and what can I license?	How big will my service area be and what are the demographics?	Do I want to expand if I already had an existing analog system?	Who is my targeted customer base and how many groups will then need?

Conclusion

This paper has presented a brief overview of the two protocols, NXDN and DMR. The intention was not to present evidence that one is better than the other since it isn't true, but to present the pros and cons based on the limitations of each.

The reader must carefully consider the basic protocol before choosing, and also consider that manufacturers will tout features that appear to offer many benefits over another manufacturer's offering. To ensure a successful deployment, it's always best to go back to the fundamentals and wise selection of a protocol is one of those fundamentals. Features alone do not make a customer happy if it turns out that their radios can't be heard or the channel even accessed.

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