KENWOOD

DMR System Guide (DMR-based Trunking)

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Revision History

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1.00	First Release

Document Revision

This document shall be changed from time to time without notice. This document is created and published for the products having the following design specifications.

Terminal Software Version

Item	Version	How to Verify
NX-3000 series	K 3.32.00	Read/Write > Transceiver Information dialog box of KPG-D3
NX-5000 series	K 4.32.00	Tools > Transceiver Information dialog box of KPG-D1

Trunked Station Software Version

Item	Software Type	Version	How to Verify
KAIROS series	Base Station Firmware	1.6.C.5	Software > Versions of KAIROS Manager
	Trunking System Controller	1.1.0.2	Software > Versions of KAIROS Manager
	DSP Software	4.67	Software > Versions of KAIROS Manager

IP Gateway Software Version

Item	Version	How to Verify
KPG-1013GW	V1.20	Maintenance > System > Firmware Update > Current Firmware of Web Interface

Programming Software Version

Item	Version	How to Verify
KPG-D3	3.30	"About" dialog box of KPG-D3
KPG-D1	4.31	"About" dialog box of KPG-D1
KAIROS Manager	1.7.14	"About..." dialog box of KAIROS Manager

Application Software Version

Item	Version	How to Verify
KPG-180AP	3.01	Help > "About KPG-180AP" dialog box of KPG-180AP
KAS-20	3.11	Help > "About" dialog box of KAS-20
KAIROS NetControl	0.9.185	"About..." dialog box of KAIROS NetControl

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Contents

1. Main Applications

This chapter explains main applications employed DMR-based digital system.

The DMR standard defines three of Tier1, Tier2, and Tier3. The following explains each feature briefly.

DMR Tier 1
It uses for PMR446 (Private Mobile Radio) applications. It is with the limited number of channels, low TX power (0.5W), and only the direct mode using no repeater. It is for small-scale communication purpose. PMR446 will not be explained in this document.

DMR Tier 2
It uses for the Conventional system and covers both of direct mode which uses no repeater and repeater mode. It employs 2 slots TDMA technology. The Conventional system will not be explained in this document.

DMR Tier 3
It uses for the Trunked system. It employs 2 slots TDMA technology.

1.1. DMR-based Trunking

DMR-based Trunking is a centralized trunked relay system that employs 2 slots TDMA technology. It provides greater traffic capacity than conventional system by using channels efficiently among system users, and it also has enhanced calling features, security and more comfortable communications.
One of the characteristic points is the system structure. The main component is a site which is built by multiple repeaters. A site consists of a certain number of payload channels, at least one control channel. A payload channel is a dedicated logical channel for voice communication or user data. A control channel (TSCC) is a dedicated logical channel for transmitting system information and receiving radio accesses.

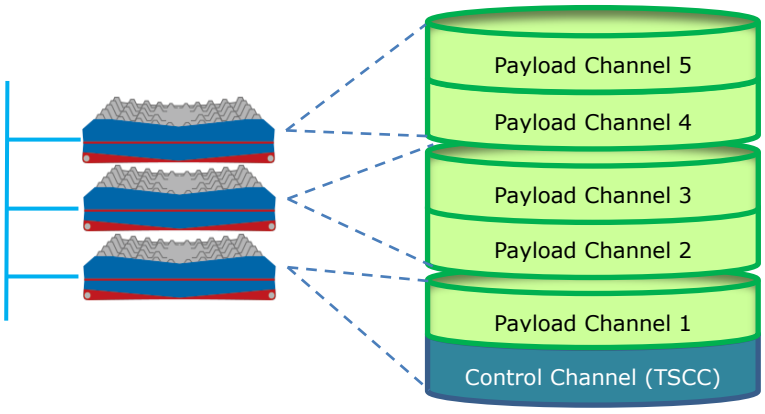


Figure 1-1 Site Configuration

Another important component is Trunking System Controller (TSC) which controls a site. It is responsible for organizing control channels and payload channels and managing the system resource.

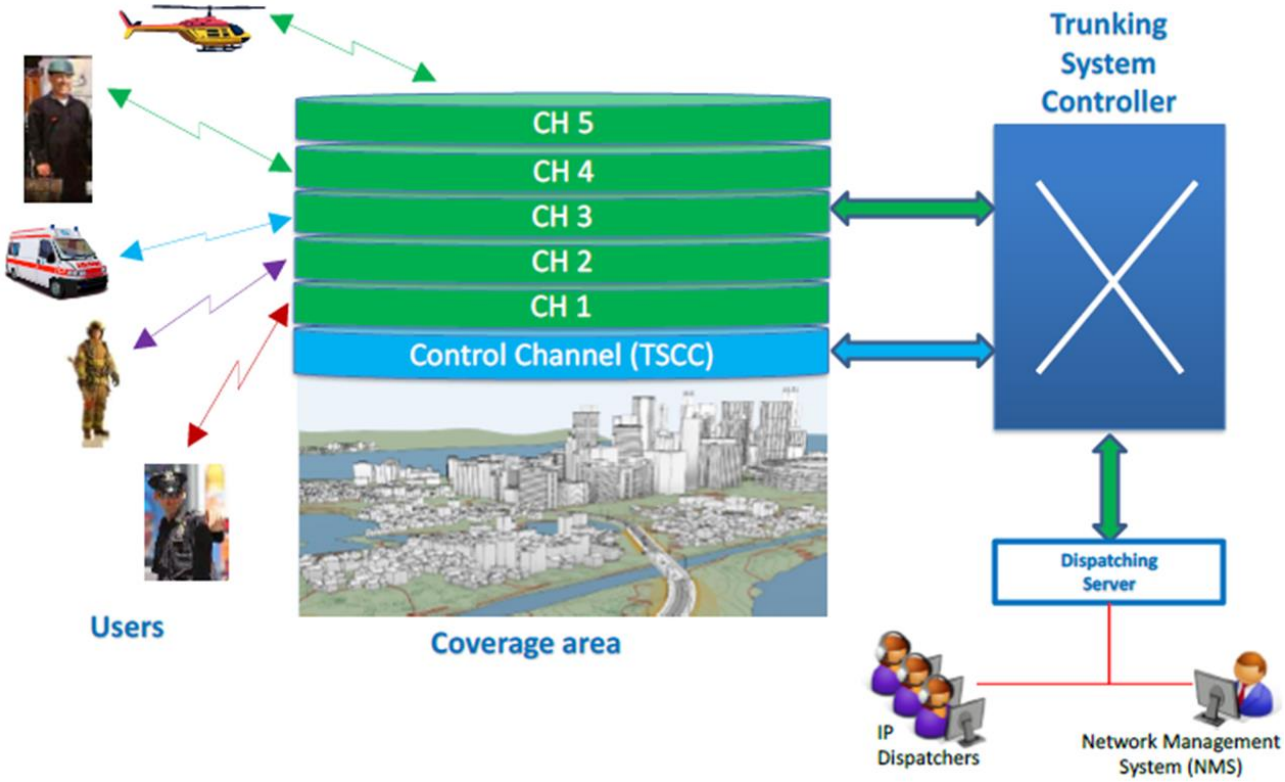


Figure 1-2 DMR-based Trunking

In the system, the number of channels may be much lower than the number of potential users. But, the use of channels is optimized as payload channels which are assigned only when needed.

1.1.1. DMR Tier III Mode

DMR Tier III Mode conforms ETSI Standards. This mode has a control channel (TSCC) transmitted continuously, and it can provide a large-scale and stable communication service.

1.1.2. S-Trunking Mode

S-Trunking Mode is JVCKENWOOD proprietary. This mode has a control channel (TSCC) transmitted intermittently. Therefore, it conforms shared channel licenses, a user shares a frequency with anther user/agencies, because a site doesn’t occupy a frequency exclusively.

1.2. DMR-based Trunking IP Network

DMR-based Trunking IP Network is a mode to expand a coverage by interconnecting multiple sites or repeaters installed in different locations over IP network. This causes a radio unit can communicate with a distant radio unit via an IP network. KAIROS series repeater which is used to build a site can connect to an IP network, and it supports both multi-site and simulcast.

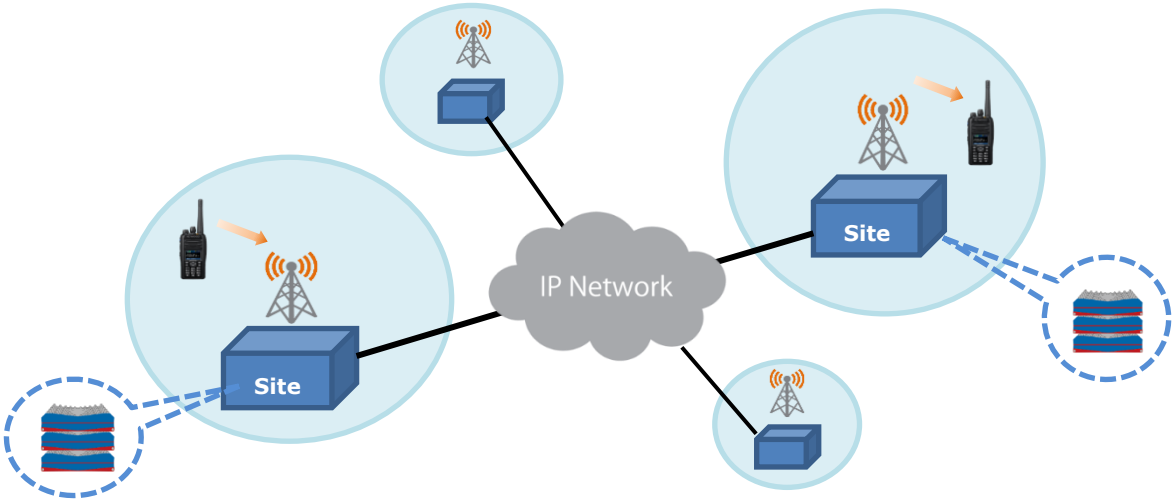


Figure 1-3 DMR-based Trunking/ IP Network

1.2.1. Multi-Site

In Multi-Site system, each site consists control channels and payload channels, and all sites can communicate each other over IP network. This technology provides us wide coverage service. A radio unit can switch a site automatically when it moves to another site's coverage area.

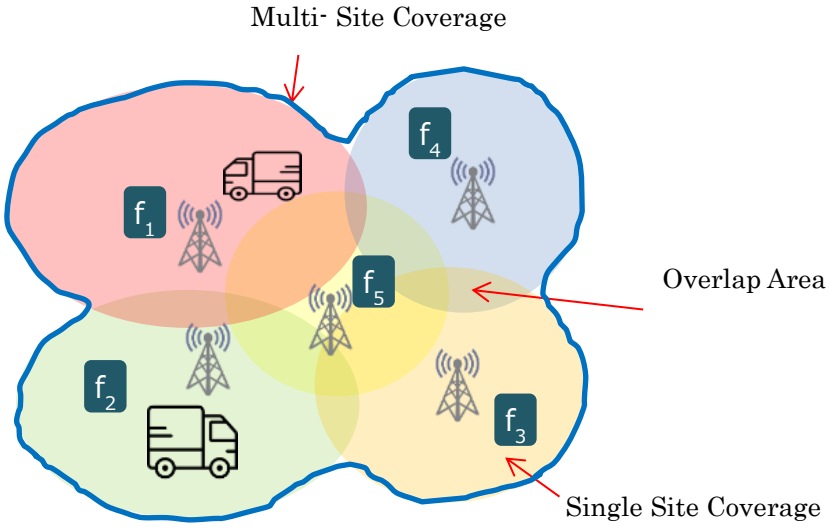


Figure 1-4 Multi-Site System

1.2.2. Simulcast

Simulcast is the technology that multiple sites, connected to IP network, synchronize each other and transmit the same signal with the same channel at the same timing, and they behave as a single "big coverage site". This technology can be used for not only the Conventional system but also the Trunking system.

Note : Simulcast is not available for S-Trunking Mode.

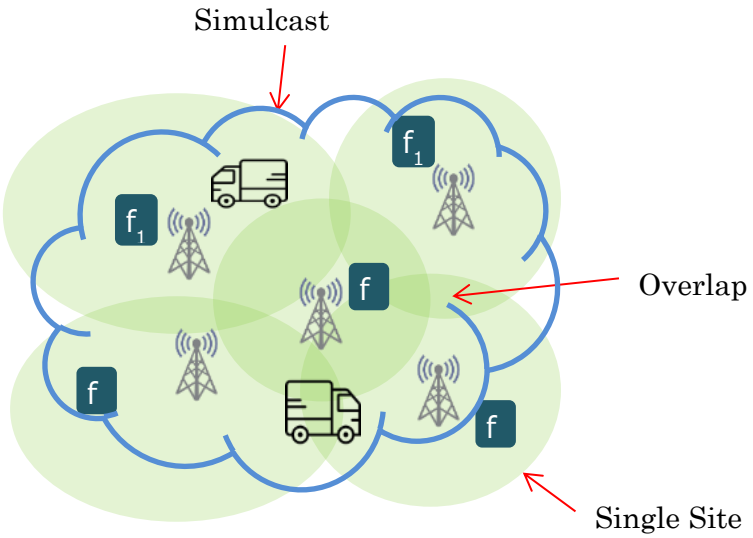


Figure 1-5 Simulcast System

2. KENWOOD DMR Feature Outline

This chapter explains an overview of the DMR function which is available with Kenwood's radio and KAIROS series.

2.1. Control Channel Hunt

Control Channel Hunt means that a radio is roaming to a site. This section explains relevant functions for Control Channel Hunt in a DMR-based Trunking system.

A radio which initiates a service on the DMR-based Trunking system must acquire the control channel (TSCC) of the site and be registered its DMR ID with the site.

A) After a radio turns on, it starts scanning a downlink (TSCC) of an available site.
B) When a radio founds the downlink of TSCC, it stops scanning and tries to register with the site.
C) If the permission for the registration is issued from the site, the radio acquires and stays the TSCC.
D) But if the registration is failed, the radio resumes scanning.
E) After registration with the site, a radio resumes scanning if it has lost the downlink of TSCC.

Radios start TSCC Hunt Sequence to find an available site efficiently, the hunting sequence is ordered as the below figure and they repeat the sequence if no signal is founded.

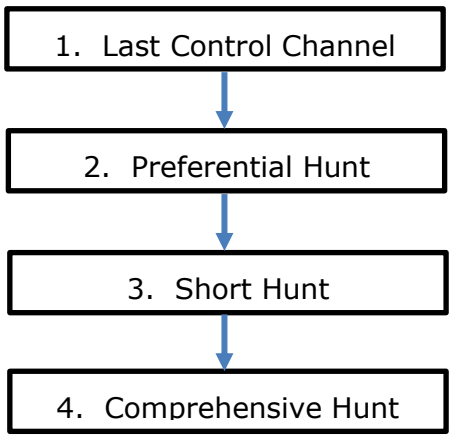


Figure 2-1 TSCC Hunt Sequence

2.1.1. Last Control Channel Hunt

Just after a radio starting up, it checks the control channel which was acquired when last powered off.

2.1.2. Preferential Hunt

Before scanning the Short Hunt table, a radio scans Preferential Hunt Control Channels which are preset by the programing software and checks them preferentially.

2.1.3. Short Hunt (Normal Hunt)

A radio scans a downlink from the frequency table that is preset by the programing software. The frequency table is called Normal Hunt Control Channel, and it means Short Hunt is the basic and efficient roaming method.

2.1.4. Comprehensive Hunt

In Comprehensive Hunt, a radio scans all channels that have possibility to be used. But this roaming method may be slow to acquire a control channel because a radio tries with many channels.

2.1.5. Background Hunt

Background Hunt is quite different from Short Hunt, Preferential Hunt or Comprehensive Hunt that work when a radio hasn’t acquired a control channel, and it works after a radio has acquired TSCC and registered with a site.
In Background Hunt, a radio checks TSCC of adjacent sites periodically, and it switches from the current to the adjacent site if the communication condition is better than the current.

2.1.6. Out of Range Indicator

If a radio can’t register with any site for a while, it starts to indicate the out of range status by a beep and a warning message on LCD.

2.1.7. Alternate Zone-Channel

If a radio is into the out of range status, it can switch to the temporary conventional mode automatically. During the temporary mode, a radio keeps the Control Channel Hunt sequence and returns to the trunking mode when it acquires TSCC.

2.2. Calls

This section explains representative functions for the call service in DMR-based Trunking.

2.2.1. Individual Call

Calling with specifying a Unit ID enables one-to-one conversation (Individual Call).
A radio requests a voice call to a site through a control channel (TSCC). The system checks the resource and assigns a free payload channel for Individual Call. After that, two radios can have a conversation on the payload channel.
Individual Call has two types, initiating a call after confirming whether or not the called radio is available to communicate (Full Off Air Call Set-Up (FOACSU)), and initiating a call without confirming it (Off Air Call Set-Up (OACSU)). FOACSU can initiate a call with ensuring a called radio is available because waiting for an acknowledgment from the called radio, and a payload channel is assigned when the called radio has answered. OACSU can initiate a call without acknowledgment from the called radio, therefore a payload channel is assigned soon after the system accept the voice call request.
You can preconfigure the type of call FOACSU or OACSU by a programing software.

Making an Individual Call

An Individual Call can be started by one of the following methods.

- Individual Call Mode
  Transmit an Individual Call by selecting a Unit ID from the Individual ID List or directly entering a Unit ID using a keypad, in Individual Call Mode.
- Talkback
  Press the PTT button while the Auto Reset Timer is counting down after the radio receives an Individual Call.
- Stack Mode
  Stack Mode is specialized mode to read incoming calls history memorized in the radio. Select a target from the history and transmit.
- Selcall on PTT
  Select a channel which is configured initiating an Individual Call on PTT button and transmit by pressing the PTT button. The Unit ID must be preconfigured to the channel by a programing software.
- Call button
  Press a Call button which is assigned the Unit ID to call. For the Mobile model, from Call 1 to Call 6 button can be also assigned to input ports of an external connector.

Alert on a radio

The following alert is available in transmission and receipt of Individual Call.

- The tone that emits when PTT is pressed (Call Request Tone)
- The tone that emits while a radio waits for a payload channel assignment (Call

Processing Tone)
- The tone that emits when a payload channel is assigned, and a voice call becomes available (PTT Proceed Tone/Call in Progress Tone)
- The tone that emits when a radio terminates a voice call and it's disconnected from a payload channel (Disconnect Indicator Tone)
- The tone that emits when a radio receives Individual Call (Alert Tone)
- The LED that blinks when a radio receives Individual Call (Selective Call Alert LED)
- The indication of caller Unit ID or caller ID name of Individual Call ※1

※1: Using the Over-the-Air Alias feature, the radio can display the caller's ID Name even if the radio receives a call from a unit ID that is not pre-registered on the call list of receiving radio.

2.2.2. Group Call

Calling with specifying a Group ID enables a call to the group members (Group Call), all the radios in the standby state with the same Group ID are called. A radio requests a voice call to a site through a control channel (TSCC). The system checks the resource and assigns a free payload channel for Group Call. After that, the group members can have a conversation on the payload channel.
Each call group must be assigned Group ID beforehand by using a programing software.

Specify the Group Call to receive

The Group IDs for receiving can be specified from the following type, and they must be preconfigured by using a programing software.

- A Group ID that is configured for the user selected channel
- Group IDs that are listed on the Group ID List

Making a Group Call

A Group Call can be started by one of the following methods.

- Selcall on PTT
  Select a channel which is configured the target Group ID and transmit by pressing the PTT button.
- Talkback
  Press the PTT button while the Auto Reset Timer is counting down after the radio receives a Group Call.

Alert on a radio

The following alert is available in transmission and receipt of Group Call.

- The tone that emits when PTT is pressed (Call Request Tone)
- The tone that emits while a radio waits for a payload channel assignment (Call

Processing Tone)

- The tone that emits when a payload channel is assigned, and a voice call becomes available (PTT Proceed Tone/Call in Progress Tone)
- The tone that emits when a radio terminates a voice call and it's disconnected from a payload channel (Disconnect Indicator Tone)
- The tone that emits when a radio receives Group Call (Alert Tone)
- The LED that blinks when a radio receives Group Call (Selective Call Alert LED)
- The indication of Group ID, Group ID Name, caller Unit ID or caller Unit ID Name※1

※1: Using the Over-the-Air Alias feature, the radio can display the caller's ID Name even if the radio receives a call from a unit ID that is not pre-registered on the call list of receiving radio.

2.2.3. All Call

A radio can broadcast a call to all radios in the system by specifying the "All Group ID". To make an All Call, "All Group ID" must be preconfigured to the radio by using a programing software. Talkback is not available when a user receives All Call.

2.2.4. Broadcast Call

Broadcast Group Call can be used to engage in one-way voice calls to the group member. Talkback is not available when a user receives the call. This call must be transmitted using the specified Group ID after enabling the broadcast feature by operating the radio.

2.2.5. Late Entry

A radio can participate in on-going voice call even if the radio receives a group call midway through in DMR-based Trunking system.

2.2.6. Telephone Call

The DMR-based Trunking system can connect to the PABX/PSTN phone system via IP Network. It needs to prepare IP Gateway, a server PC which is installed a specific software, to connect between a radio system and a phone system. A radio can make a conversation with a phone as well as Individual Call or Group Call.

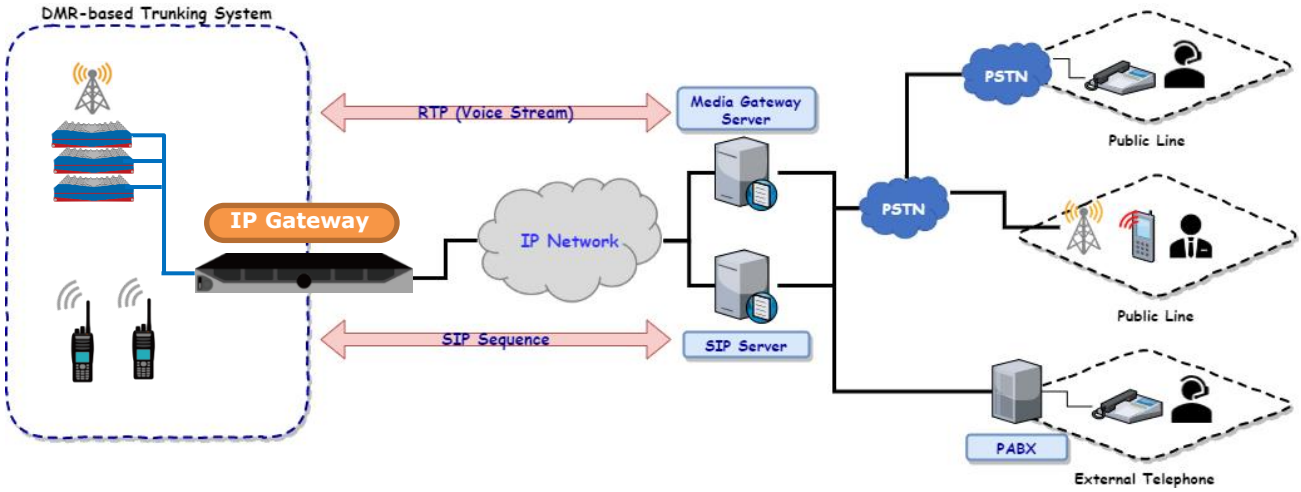


Figure 2-2 Telephone Call

2.3. Call Interruption

Call Interruption is a function that a radio can initiate a call by interrupting the ongoing call when a payload channel is occupied with another talker. This function is useful in case that a radio initiates the preferential or emergency call. In DMR Tier III Mode, NX-3000/5000 series and KAIROS series support this function with ETSI DMR Standard.

2.4. Over-the-Air Alias

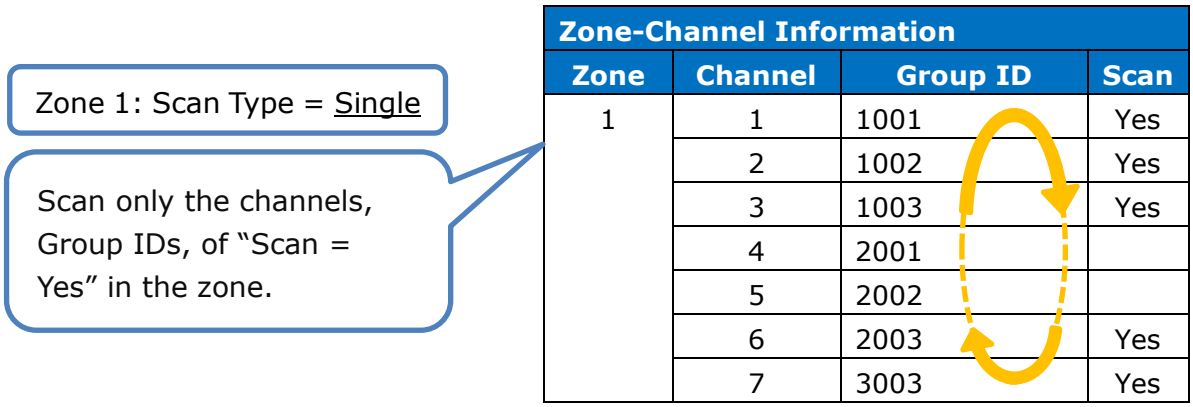
Over-the-Air Alias is a feature that a target radio can display the ID Name of a caller radio by receiving a voice call including Caller ID Name. This feature is useful if some radios must be added to the system while it’s operating, because the additional configuration, such as new radio's Unit ID Name, doesn’t have to write to current operating radios.

2.5. Scan

Scan has following two types in DMR-based Trunking system.

- Single Zone Scan

  A radio scans target channels, Group IDs, in the same zone.

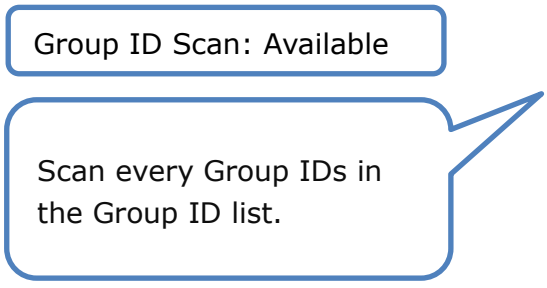


Zone-Channel Information			
Zone	**Channel**	**Group ID**	**Scan**
1	1	1001	Yes
	2	1002	Yes
	3	1003	Yes
	4	2001	
	5	2002	
	6	2003	Yes
	7	3003	Yes

Figure 2-3 Single Scan

- Group ID Scan

  A radio scans target Group IDs in the preset Group ID list.



Group ID List		
No.	**Group ID**	**Group Name**
1	1001	Group 1001
2	1002	Group 1002
3	1003	Group 1003
4	2001	Group 2001
5	2002	Group 2002
6	2003	Group 2003

Figure 2-4 Group ID Scan

Each type of scan's behavior depends on the configuration of the zone-channel that is selected when Scan is started.

Starting a Scan

Single Zone Scan can be started by one of the following methods.

- Pressing the Scan button (toggle operation)
- Selecting in Menu Mode (toggle operation)
- Operating the lever switch (Portable radio only)
- Switching the AUX Input port (Mobile radio only)
- Switching the microphone hook status (Mobile radio only)
- Turning on the power (If Power-on Scan function is enabled)

- Selecting the channel enabled Auto Scan function

Group ID Scan works automatically by selecting the channel enabled Group ID Scan, but it doesn't work simultaneously with Single Zone Scan.

Revert Channel
Revert Channel is the zone-channel which is used when the radio transmits by pressing the PTT button while Single Zone Scan is running. The following type can be selected for Revert Channel.

- The last-called zone-channel (when scanning)
- A channel where is paused scanning (when paused of a scan)
- The changed zone-channel if the zone-channel is changed.

2.6. Emergency

When emergency situations occur, a radio can enter Emergency Mode automatically or manually, and it repeats transmission for emergency purposes. Transmitting with sound around the microphone together is useful to know how the emergency status is. In addition, Emergency Status Message can be sent to let a receiver know the trigger of the emergency.

The behavior of the radio in Emergency Mode has two types of Audible and Silent. Setting to Audible type, the radio emits the received audio from the others, such as a base station, in the same manner as in normal mode even while in Emergency Mode. The people around the radio in Emergency Mode can know the place of the emergency occasion by emitting Locator Tone from the radio. Setting to Silent type, the radio mutes any sound even if the radio receives a signal. If the power switch to be off, it seems that the power turns off, but in fact, it does not off the power and Emergency Mode continues. Silent type is useful that the user in Emergency Mode does not want the people around there to know the radio is Emergency Mode.

Receiving an Emergency Status, a radio displays text strings that show the kind of emergency. Receiving an Emergency Alarm, a radio notifies the user of receiving the alarm by the display, tone or Horn Alert.

The radio enters Emergency Mode by the following triggers.

- Pressing the Emergency button
- Switching the AUX Input port assigned for Emergency (Mobile radio only)
- Lone Worker (the situation that the radio is not operated for a certain period of time)
- Man-down Detection (the situation that the radio becomes tilted continuously for a certain period of time)
- Stationary Detection (the situation that the radio becomes stationary continuously for

a certain period of time)
- Motion Detection (the situation that the radio is shaken strongly or swung continuously for a certain period of time)
- Heart Rate (the situation that a heart rate sensor connected with a radio by Bluetooth LE detects the heart rate of out of range configured)
- Injury Detection (the situation that an injury sensor connected with a radio by Bluetooth LE detects a damage)

It is possible to be configured which zone-channel is used in Emergency Mode, either a specified channel (pre-configured) or a channel selected currently is used. The destination must be set either a specific Unit ID or Group ID beforehand by a programing software.

2.7. Data Service

This section explains the message and data which can be communicated in DMR-based Trunking system. A destination of data (Base ID) can be configured for each system.

2.7.1. Status Call

Using Status Call feature allows communicating simply by sending Status numbers which are configured a fixed message beforehand in both of caller and called radio. Since the message is replaced by status number, communication traffic can be reduced.

Basically, a destination of Status Call is Base ID, but it is possible to select a Unit ID or Group ID by operating the radio and send.

The behavior of a radio receiving a Status

Receiving a Status emits Alert Tone and displays the received message and ID of the sender. The message is displayed depending on a preconfigured list of correspondence between the Status and the message.

Received Status messages can be stored in the stack memory (receive history). A user can read them in Stack Mode which is the specialized mode for the incoming call history.

Sending a Status Message

- In Status Mode, select a Status from a Status List or directly enter a Status number by the keypad. And then, send the Status by pressing the PTT button or [Send] button.
- Assign the Status sending function to the Call button. And then, send the Status by pressing the Call button.

Automatically send a Status message depending on the situation

In the following situations, a radio sends a Status message automatically.

- When the power of radio becomes on or off.
  This is useful if a user needs to inform a starting of work or a turning off the radio to a console.
- When the AUX-input port switches Low or High.
  For example, if a water level sensor at a river connects with the AUX-input port, the radio automatically sends the Status message when the water level goes to the specified level and the AUX input port is switched. By using this way, the situation can be grasped in a timely even from a remote place.

2.7.2. Short Data Call

Text strings can be transmitted and received in DMR-based Trunking system. For Group Call, up to 365 characters can be sent and received. For Individual Call, up to 489 characters can be sent and received.

Basically, a destination of Short Data Call is Base ID, but it is possible to select a Unit ID or Group ID by operating the radio and send.

The behavior of a radio receiving a Short Message

Receiving a Short Message emits Alert Tone and displays the received message and ID of the sender.
Received Short Messages can be stored in the stack memory (receive history). A user can read them in Stack Mode which is the specialized mode for the incoming call history.

Sending a Short Message

- Enter a message manually in Short Message Mode. And then, send a Short Message by pressing the PTT button or [Send] button.

2.7.3. Long Data Call

Long Data Call is JVCKENWOOD proprietary feature. Up to 4096 bytes of text strings can be transmitted and received in DMR-based Trunking system. Long Data Call works for communicating via radios between external devices such as an MDT or PC.

A transmitting message must be input from a device connecting to a radio by a serial interface, or an application connecting to a system by IP network. And, a received message is output by serial data from a receiver, or IP packets from a system. A message is not shown on the display of the radio even if it receives Long Data Call.

2.7.4. Transparent

Transparent is JVCKENWOOD proprietary feature. It is possible to communicate a simple serial data output from external devices such as a card reader or barcode reader between two radios. It is used for a telemetry system and so on. It supports sending and receiving a data that is compliant with Serial Interface Protocol. The connection between a radio and an external device uses a serial interface port or Bluetooth serial port.

When serial data is inputted from an external device to the radio, the radio automatically sends the data with no operation, and then the data received by another radio will be automatically outputted to an external device. In DMR-based Trunking system, the data is divided into data blocks of 1496 byte per one block and sent.

2.7.5. GPS Report

The radio which is equipped with a GPS unit can send GPS data to a base station or so on.

Timing of GPS Report

GPS data can be automatically sent at the timing configured beforehand or sent by responding to a Polling request.

Timings of automatically sending are the followings.

- The time intervals
  When the preset time has passed from the previous sending.
- When moving the fixed distance
  When a radio has been moved the distance configured beforehand from the previous sending. Using this setting for the radio which moves a little, saves the battery and traffics.
- When sending the specific Status
  This setting grasps a location in the situation that the specific Status is sent, but not periodically.
- When communicating by Voice Call
  This setting grasps a location in situations that a voice call is started, but not periodically.

Destination of GPS Report

Basically, GPS Report is sent to the Base ID, preset by a programing software, of the current system as well as the other data call is. If sending only the GPS Report to a specific destination is needed, the dedicated Unit ID or Group ID can also be set.

2.7.6. Unified Single Block Data (USBD) Polling Service

In DMR Tier III Mode, USBD Polling Service enables GPS data to be polled from a radio which has registered on a control channel (TSCC). The opposite time slot of TSCC can be set as Trunk Station Control Channel Alternate Slot (TSCCAS), and it's used as a dedicated logical channel for GPS polling. NX-3000/5000 series and KAIROS series support it with ETSI DMR Standard.

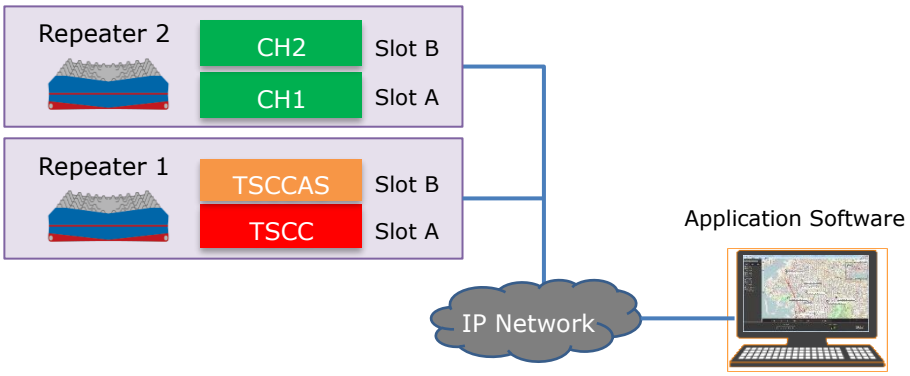


Figure 2-5 Single Site (1 TSCC, 1 TSCCAS, 2 Payload channels)

This service is very efficient, allows data to be packaged minimizing, reduces delays between one sending and the other, avoids conflicts and supports large quantities of location updates. GPS capacity is 50, and it means the system can collect 50 GPS data every 1 minute by using USBD Polling Service.

2.8. Remote Control (Radio Unit)

Using remote operation by radio communication can control a specified radio individually. When a radio or a system sends messages for remote control and a target radio receives the message, the target radio can be controlled.

Controllable functions are the followings.

- Remote Monitor
  It makes a target radio transmit for a certain period of time. Monitoring sound around there via the microphone of the radio is capable.
- Radio Check
  It makes a target radio transmit a Status call as an Acknowledgment. Checking whether the target radio is working or not is capable.
- Remote Stun
  It can be disabled a target radio, and a disabled radio can return to available by receiving a Revive message or reprograming. Authentication Key can be used to not accept a Stun message from the wrong system.
- Remote Kill

It can be disabled a target radio, and a disabled radio can only return to available by reprograming. To use Remote Kill, Authentication Key is required to not accept a message from the wrong system.

- Remote Revive
  The Stun state of a target radio can be released if the target radio is in the Stun state. Authentication Key can be used to not accept a Revive message from the wrong system.

2.9. Scrambler/Encryption

Encrypting data such as a voice or Short Message can enhance secrecy in communications on the DMR digital channels.

The following encryption types are available for NX-3000/5000 series.

- Bit Scramble
- Enhanced Encryption (ARC4) *
- DES
- AES

*Enhanced Encryption (ARC4) is only available for DMR Tier III Mode.

The secrecy of encryption increases in the following order.
Bit Scramble < Enhanced Encryption (ARC4) < DES < AES

Configuring each channel to enable or disable beforehand is needed to make an encrypted communication. By manually operating a radio, an encrypted communication on the selected channel can switch to disabled or enable. The data remains encrypting on the communication path such as a repeater connected via IP.

2.9.1. Encryption Key

To decrypt an encrypted communication uses the Encryption Key configured in the radio or SCM (Secure Cryptographic Module). Though Encryption Key is configured on the channel beforehand, it can be changed by manually operating the radio at transmitting. Encryption Key can be deleted depending on the setting when a radio is stolen.

2.9.2. Bit Scramble

Bit Scramble is the simplest encryption type. Only voice data is encrypted. A radio decrypts a received data using the Encryption Key configured on the received channel.

2.9.3. Enhanced Encryption (ARC4)

Enhanced Encryption (ARC4) is only available for DMR Tier III Mode. The internal memory

in a radio has Encryption Key.

2.9.4. DES

For DES, the internal memory in a radio or SCM (Secure Cryptographic Module) has Encryption Key.

2.9.5. AES

AES is the most enhanced encryption type using 256-bit key length.

2.10. Task Request

NX-3000/5000 series has Task Request feature which manages tasks using Short Message in the DMR-based Trunking system. Using this feature can use a solution system such as HotSOS.

The task manager can send task directions to a user from the dispatch console. The receiving user can respond to the task instruction by a simple operation with the user's radio.

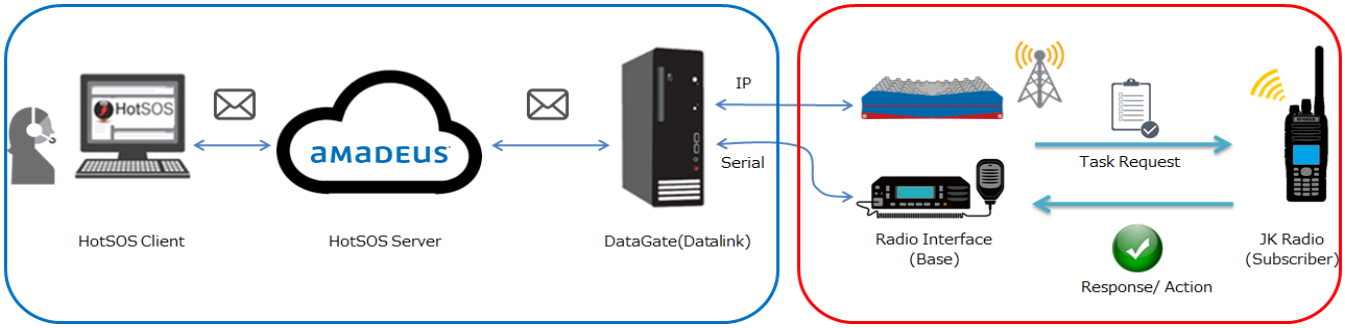


Figure 2-6 Example of Task Request System

Because the task status automatically changes depending on the response from the radio user, both the task manager and the radio user can know the task status easily.

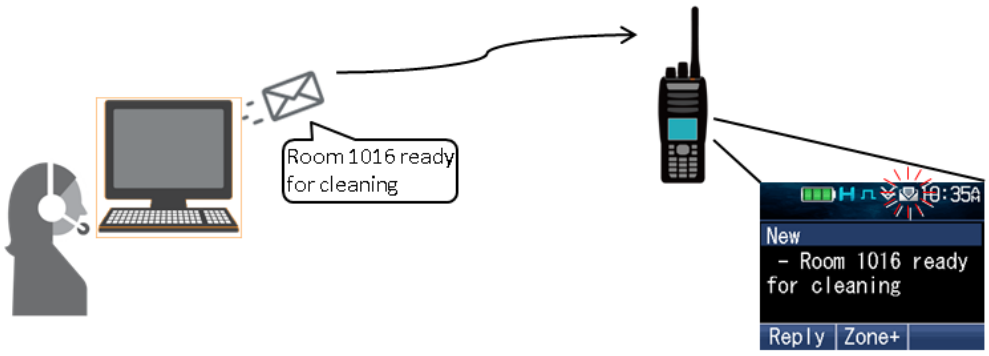


Figure 2-7 Task Request Image

2.11. PC Interface Protocol

The communication between a console application and a radio uses the Kenwood original command (PC Command). A radio can be controlled from an external device by using a serial data interface. For example, Calls, Data Services, Task Request so on. Various commands are prepared, but there are divided into the following three groups.

Control Command
Generally, these commands are used to control the radio. They make the radio which is connected via COM port transmit calls or data messages.

Response Command
These commands are used to respond to the Control Command. The radio responds whether the receiving control command can be executed or not, and then responds execution result of the command.

Information Command
These commands are used to inform an external device about the radio status or information. They are output when the radio status is changed, the PTT button is switched, the battery voltage falls during the transmitting, the radio receives data messages and so on.

2.12. User List

User List is a feature, on Trunking System Controller (TSC), to register a radio information by associating with Individual ID. A system administrator should manage the list beforehand to allow a user to initiate a service on the DMR-base Trunking system, and a radio which is not registered on the list can’t access the system.
In User List, some optional features such as Authentication Key, Call Priority, Call Rights and so on can be set for each Individual ID.

2.13. Group List

Group List is a feature, on Trunking System Controller (TSC), to register a talk group information by associating with Talkgroup ID. A system administrator should manage the list beforehand to allow a user to use Group call on DMR-base Trunking system.
In Group List, some optional features such as Call Priority can be set for each Talkgroup ID.

2.14. Repeater Remote Control

By using PC applications or repeater functions, a user can remotely manage a repeater and a system.

Checking statuses of a repeater
You can monitor a status of a repeater via IP network. In another way, a repeater can send a warning to a radio by DMR messages if it detects any problems.

Rebooting a repeater
You can reboot a repeater via IP network.

Writing a software
You can write a software to a repeater via IP network.

Setting configurations of a repeater
You can set up various configurations of a repeater via IP network.

Setting configurations of Trunking System Controller (TSC)
You can set up various configurations of TSC via IP network.

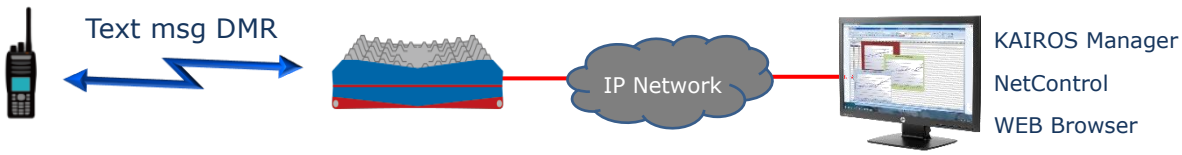


Figure 2-8 Repeater Remote Control

2.15. Fleet Dialing Plan

Fleet Dialing Plan is designed that a device which is equipped keypad may address a destination and select available features.

On the user interface, a fleet dialing number is used for addressing. For an Individual address, a fleet dialing number is configured from Number Prefix (NP), Fleet Individual Number (FIN) and Individual Number (IN). For a Group address, that is configured from Number Prefix (NP), Fleet Group Number (FGN) and Group Number (GN).

A fleet dialing number can be converted to a normal 24-bit DMR ID, and the number input from keypad is translated to 24-bit number (DMR ID) for the Air Interface between a radio and a repeater.

2.16. TSC Redundancy

A DMR-based Trunking system is configured by some repeaters which have 2 logical channels and Trunking System Controller (TSC). All repeaters and TSC should be assigned IP Address and connect each other through the IP network.

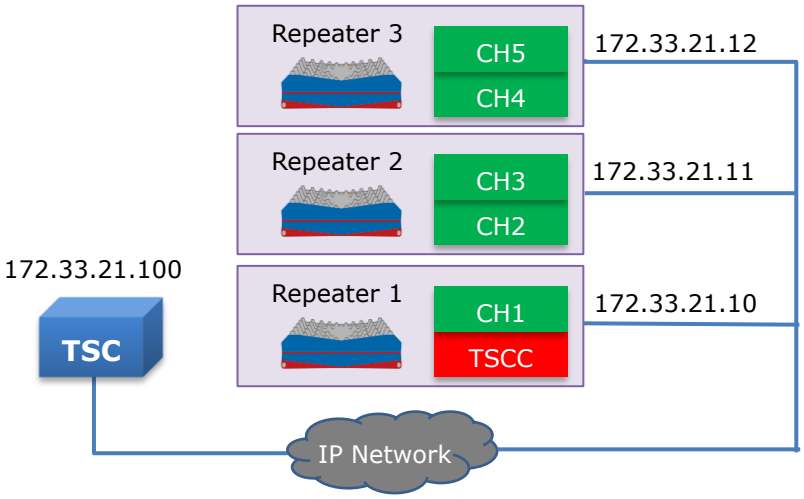


Figure 2-9 DMR-based Trunking

Trunking System Controller (TSC) is an important component and responsible for organizing control channels and payload channels, and it manages the system resource.

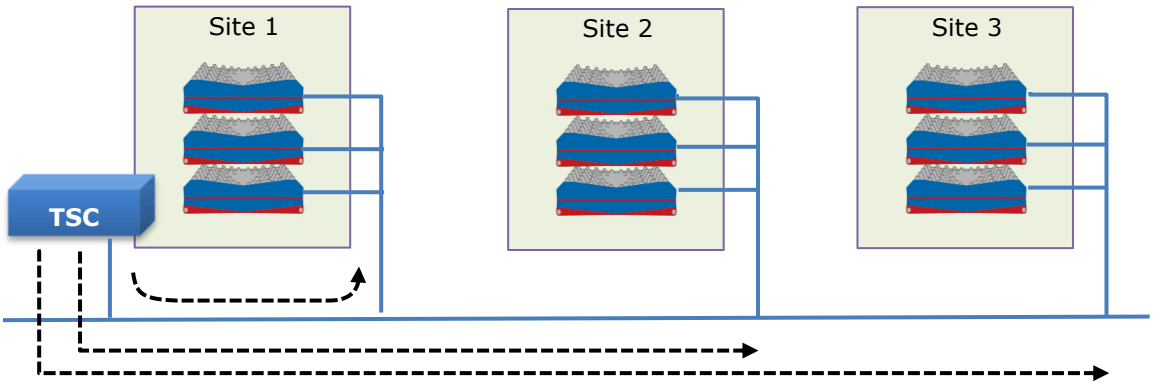


Figure 2-10 DMR-based Trunking

But the whole system doesn't work correctly if it has lost TSC by some reason.

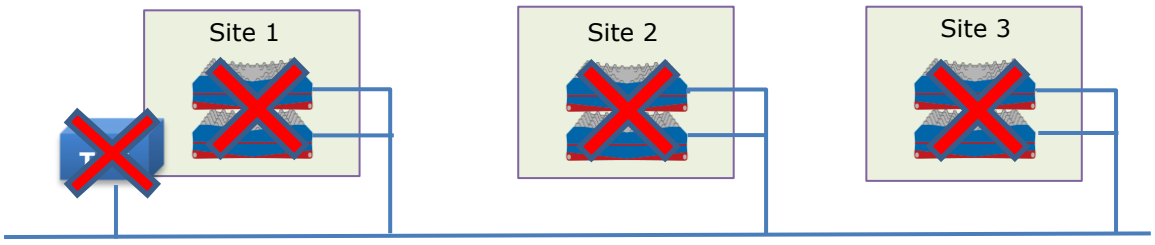


Figure 2-11 DMR-based Trunking

So, KAIROS series has some redundancy methods to prevent a system failure.

2.16.1. TSC Fail-Over

One of the redundancy methods is to prepare a backup of TSC.

The following figure is a site which has backup TSC in the DMR-based Trunking system, and the backup doesn't work while main TSC works normally.

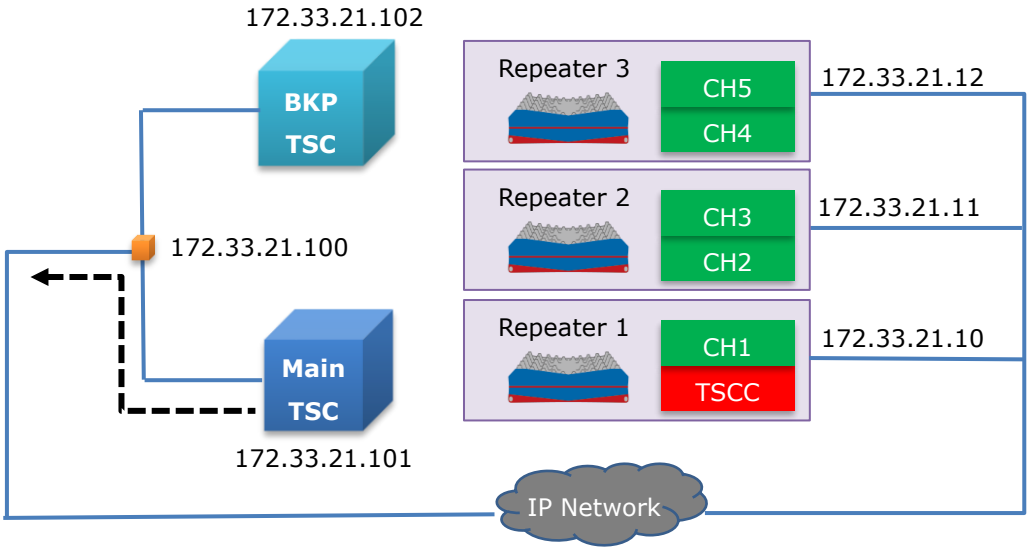


Figure 2-12 DMR-based Trunking

In case the main TSC got a problem, the backup TSC takes over TSC role to work continuously as a DMR-based Trunking site.

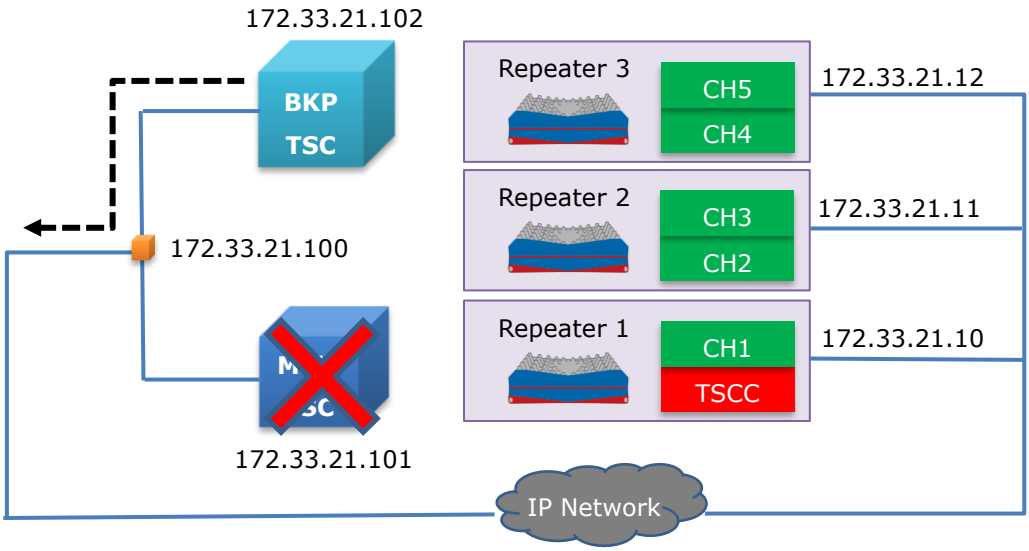


Figure 2-13 DMR-based Trunking

2.16.2. Load Balancing TSC

The other redundancy method is to prepare TSC for each site, and each TSC works normally unlike a backup (Fail-Over).

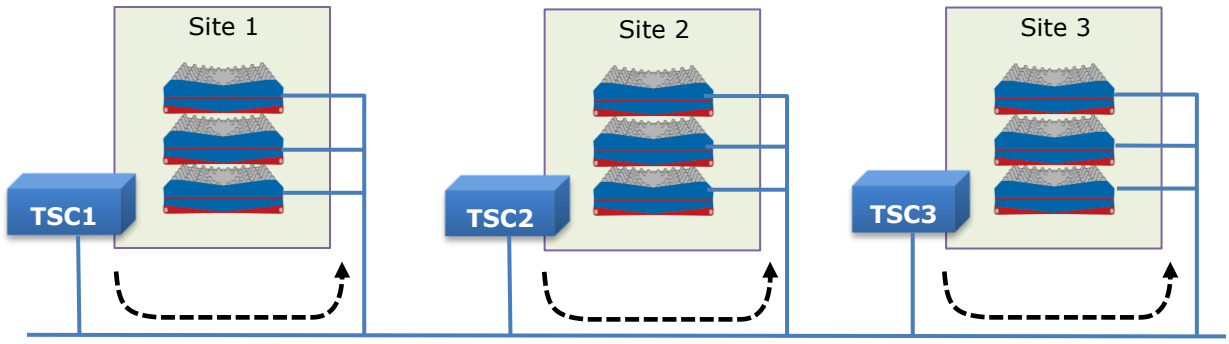


Figure 2-14 DMR-based Trunking

In case one of TSC has a problem, the site losing TSC is downed, but other sites work continuously as DMR-based Trunking sites because they link to other TSC.

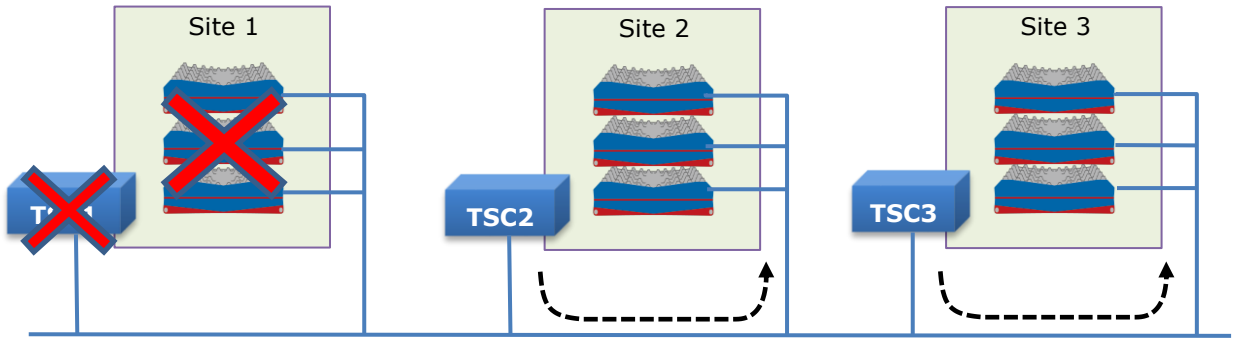


Figure 2-15 DMR-based Trunking

2.16.3. Load Balancing TSC with Fail-Over

Load Balancing and Fail-Over can be used in combination.

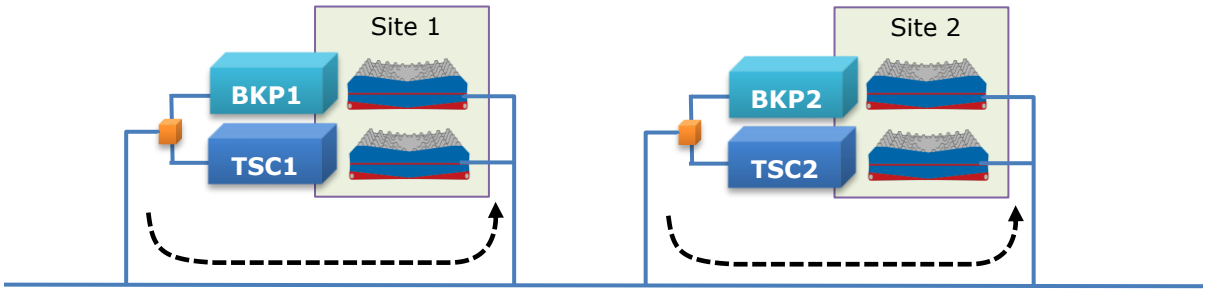


Figure 2-16 DMR-based Trunking

3. Network

The IP network will require the use of third-party products such as a switching hub or router equipment. If a site connectivity is to be provided using the public Internet, VPN technology is required for security and operation. It is also recommended for private IP networks unless the system is the sole user of the network. A network engineer is highly recommended for configuring the network.

3.1. Network Infrastructure

There are several network configurations that may be considered for interconnecting sites. This configuration will be dictated by the system administrator based on their needs, and the needs of the system are in terms of the bandwidth, the environment, and the existing infrastructure.
The following are several possible configurations that could be employed.

Microwave
Point-to-point microwave links may be used to establish a private network for the system. This is commonly used in land mobile systems to establish connectivity between sites. Due to the line of site nature of microwave, careful siting of the microwave links and choice of frequency bands are extremely important. This closed system of site connectivity will offer the highest level of security, and it will be the least affected from outside influences such as malicious network attacks. It has its own set of challenges that the system administrator must understand.

IP-VPN service
A closed IP network with VPN is independent from the public Internet. The security improves because the public Internet is not used. A closed company or agency Wide Area Network (WAN) is considered part of this methodology. If this method is used, the close attention must be paid to the other users on the network, to ensure the system is providing the adequate bandwidth and the quality of service required by the radio system.

3.2. IP Network Connection

3.2.1. Interface Devices

Switching Hub
A switching hub which has more than three ports is a network device to structure LAN. The data is sent to only the port which is connected to the device of the destination depending on the MAC address of the destination in the received data. Multicast system

must use a switching hub with IGMP Snooping feature.

Router

The Router is a network device to connect between different networks. The router sends the data to only the port which is connected to the device of the destination depending on the IP address of the destination of the data.

Routers have a user interface to set that how the processing of traffic by the router. For example, a broadband router has a function to hide computers behind a single type of firewall. Large-scale routers have features that is a high-level programming language to be able to write how the router should behave and so on, or that can decide the best way to get the network traffic from point A to point B by communicating with other routers.

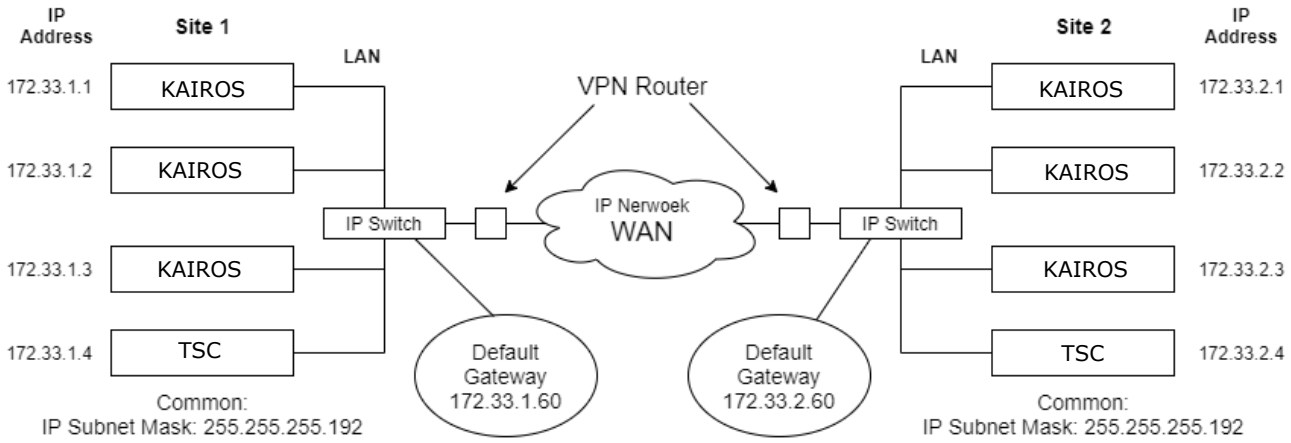


Figure 3-1 example of connection

3.2.2. Network

IP Links

When connecting a DMR-based Trunking system via an IP link, the following circumstances should be considered. There are many different variations of wireless or wired IP links available. Some of which are more suited to a mission-critical radio system application than others.

Below a non-exhaustive list of possible IP networks.

- Customers internal, own IP network
- Commercial ISP (Internet Service Provider)
- IP sections within a bigger IP network - so called Virtual Network
- Transceiver IP Link
- Microwave IP Link

Public IP Networks

Public IP Networks are available for a reasonable commercial value in most areas. Internet Service Providers (ISP's) offer various services that can range from 128 kbps

to 10 Mbps or more.
While these offers present a good commercial value, they do potential drawbacks. The system integrator/ installer and end user have no direct influence on the quality of service offered through these ISP's. If a technical fault has occurred with the ISP's hardware or software or other components, the system integrator and end user are required to wait until the ISP or responsible party has rectified that fault.
A potential loss of income, certainly loss of inter-site service and operational problems could be the result. A service level agreement (SLA) should be part of the contract with a public ISP, whenever possible.

Private IP Networks
Although more expensive than a solution based on Public IP Networks, they offer a better and more controllable quality of service.
There are several options. The best of service is depending on the budget and available resources and the customer's requirements.

- Use of customers' existing IP network
  - Consider network capacity required and security implications
  - Use IP switch with VPN facility to secure radio networks IP access
  - Consider Virtual IP Network within the customer IP network
- Build new IP interlink network
  - Wireless network
  - Consider network capacity requirements
  - Consider security requirements
  - Consider network redundancy requirements
  - Consider obstacles existing and not yet existing
  - Wire or GBN (Ground Based Network) based network
  - Consider network capacity requirements
  - Consider security requirements
  - Consider network redundancy requirements

3.3. IP Bandwidth Requirement

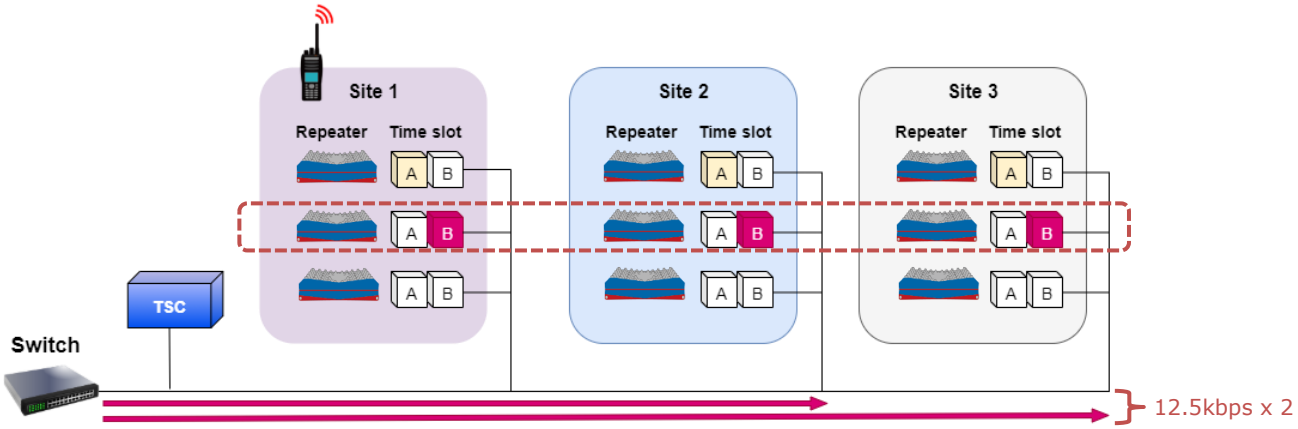
Network bandwidth calculations must be discussed in the system design phase considering network type, system size, and future system expansion.

IP bandwidth calculation should be done not only for voice communication (VoIP) but also a console call session initiation process (SIP) which occurs when every console call is made.

For the multicast network, required bandwidth is just one voice session for core router basically. In case of a VPN connection, the amount of data varies by Encryption and Authentication method. Therefore, the VPN connection is not in the scope of this section.

3.3.1. KAIROS series

Following figure is an example of a DMR-based Trunking system constructed from one Trunking System Controller (TSC) and 3 sites. Each site has 1 control channel and 5 payload channels.



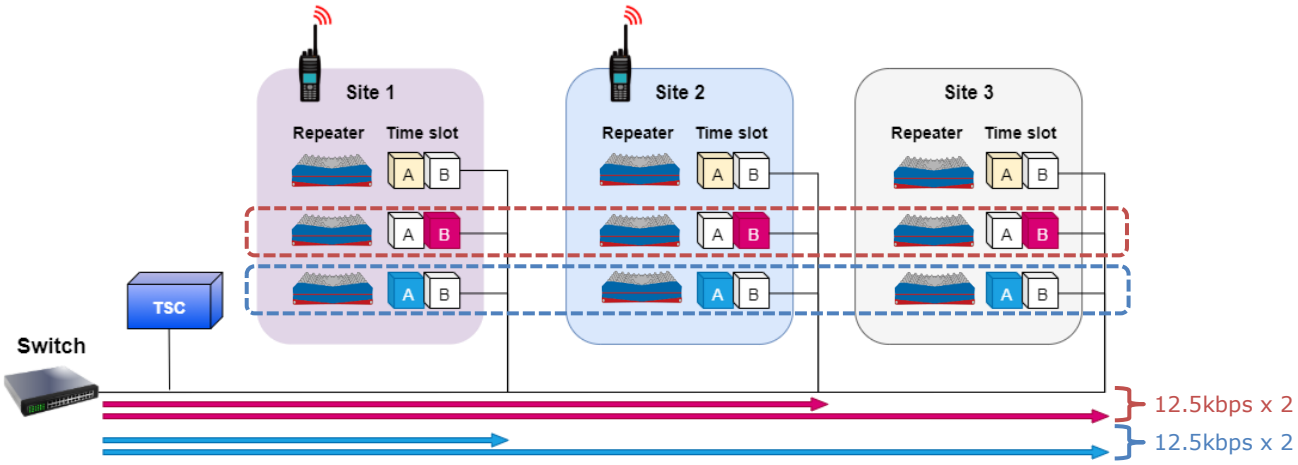
*Time Slot A of Repeater 1 is a control channel.

Figure 3-2 A voice call on the DMR-based Trunking system

This figure describes a radio under Site 1 transmits a voice call, and Time Slot B of Repeater 2 is assigned for the voice communication in each site.

In this case, voice streaming is transferred to site 2 and site 3, and single streaming is 12.5kbps. Therefore, 25kbps is required in totally.

As the next case, another radio under Site 2 transmits another voice call at the same time, and Time Slot A of Repeater 3 is assigned for the voice communication in each site.



*Time Slot A of Repeater 1 is a control channel.

Figure 3-3 Two voice calls on the DMR-based Trunking system

Another voice streaming is transferred to site 1 and site 3. Therefore, 50kbps is required in total with the already existing.

From the above, the IP bandwidth of multiple sites (with one TSC) is calculated from the following formula.

$$\textbf{IP Bandwidth} = (N_S - 1) \times N_P \times 12.5 \text{ [kbps]}$$

NOTE: N_S: the number of sites
N_P: the number of payload channels (per site)

4. Tools and Applications

This section shows the tool and application which are supported in DMR-based Trunking system.

4.1. IP Gateway (KPG-1013GW)

KPG-1013GW is a Linux based server, and it's a gateway between a DMR-based Trunking system and IP connected tools.

Dispatch applications, voice loggers or so on can access to the radio system through the IP Gateway.

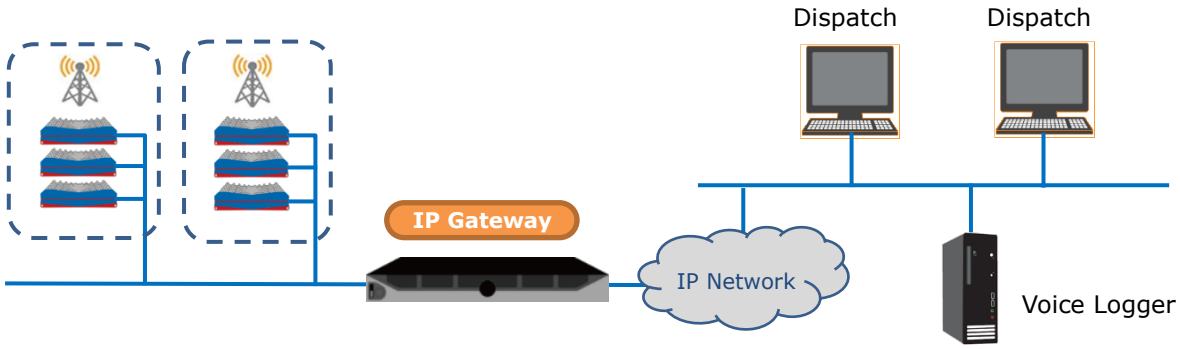


Figure 4-1 KPG-1013GW (IP Gateway)

KPG-1013GW is also responsible for connecting between a DMR-based Trunking system and a PABX/PSTN phone system via IP Network.

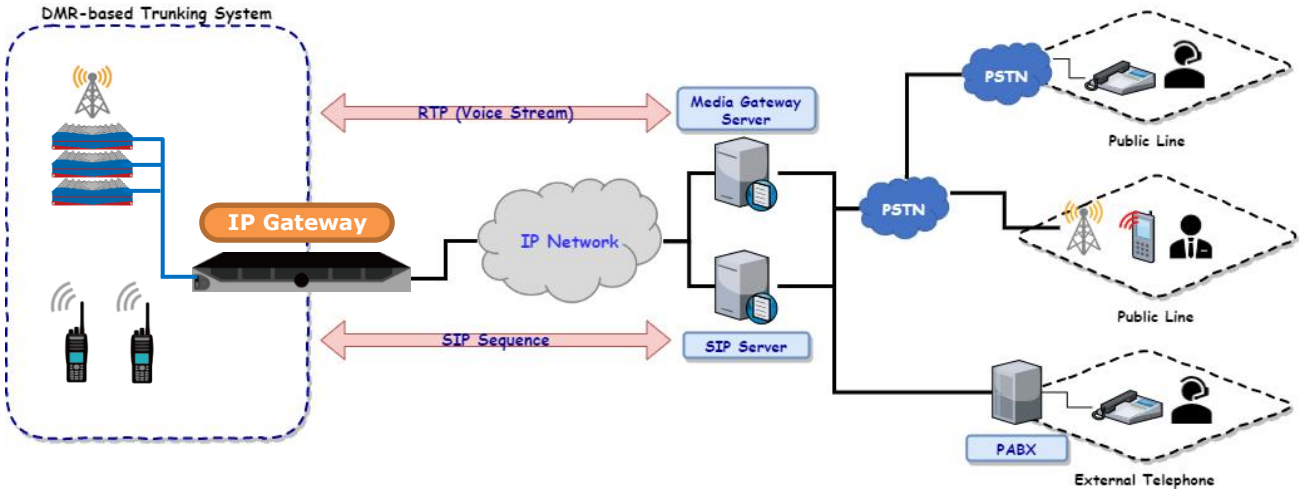
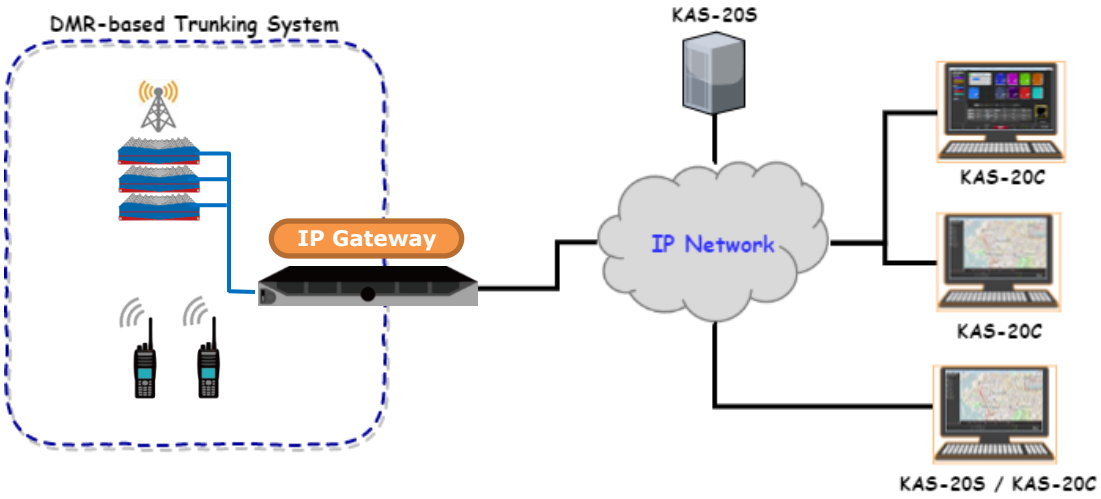


Figure 4-2 Connection for a phone system

4.2. Dispatching Solution (KAS-20 AVL & Dispatch Software)

KAS-20 AVL & Dispatch is a system application which can track, manage or communicate with mobile stations worked in the DMR-based Trunking system.

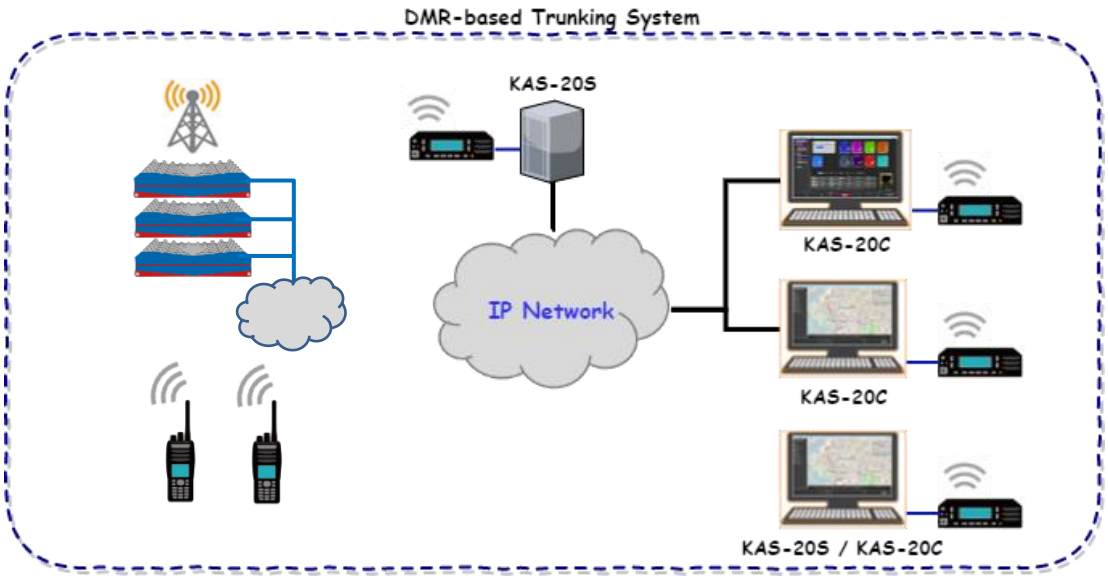
There are 2 types connection. One is the IP connection, the communication data are transferred between a radio system and KAS-20 over IP network, and operators don't have to be in a radio system area. KAS-20 has built-in vocoder and makes it possible to use a microphone and a speaker attached on PC. IP Gateway (KPG-1013GW) is required as an equipment for the IP connection.



KAS-20S: KAS-20 server KAS-20C: KAS-20 Client

Figure 4-3 IP Network Connection

The other one is the DMR air communication, a base radio connected to PC by a serial interface is required, and it communicates with a radio system as a terminal. Through a serial interface, KAS-20 controls a base radio and receives information from it. IP network is not always necessary, but a base radio must be in a DMR-based Trunking system area. The voice streaming doesn't pass through a serial interface, so an operator must use a microphone and a speaker attached on a base radio.



KAS-20S: KAS-20 server KAS-20C: KAS-20 Client

Figure 4-4 DMR Air communication

KAS-20 is consisted of the server (KAS-20S) and the client (KAS-20C). KAS-20S and KAS-20C can also install to the same PC.

KAS-20C is a client software equipped with multiple consoles including functions for initiating voice calls and for managing the positional information of the radios. It can perform functions related to voice calls, text messages, and remote control. And by gaining access to KAS-20S from KAS-20C, KAS-20C can save or browse communication logs and acquire the location information of the radio. At the same time, by accessing the KAS-20S and sharing the database of multiple KAS-20C units, information such as the positional data and voice call logs can be shared.

The following figure shows the data flow of KAS-20.

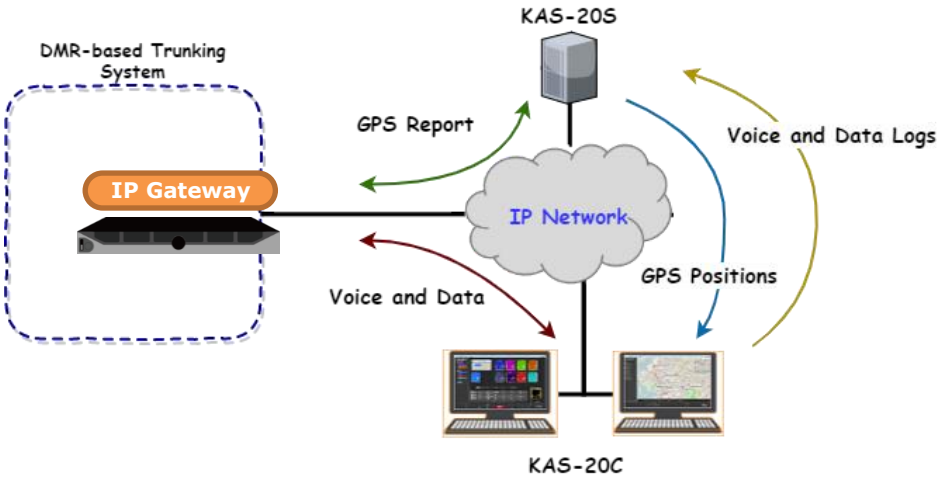


Figure 4-5 Data flow for IP Network Connection

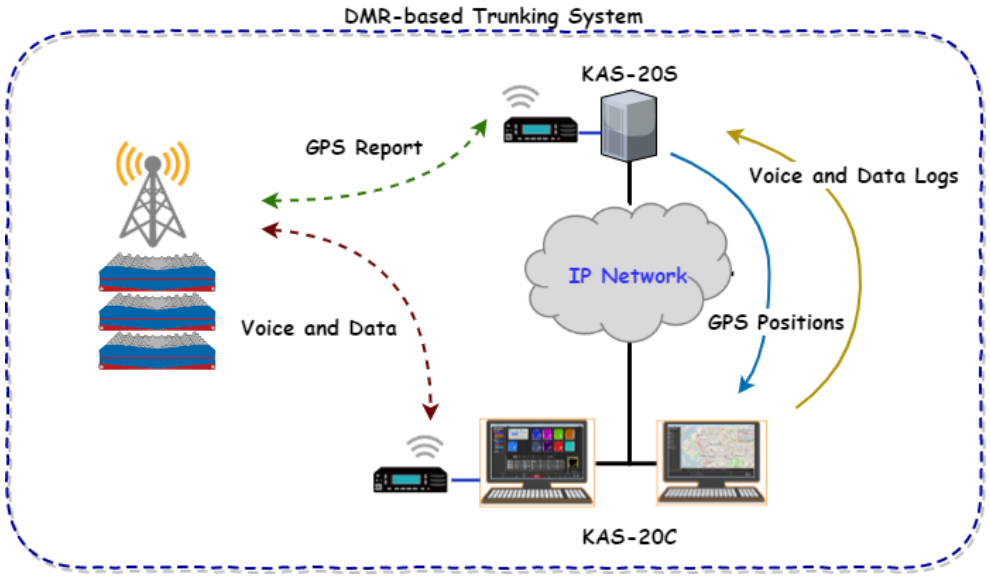


Figure 4-6 Data flow for DMR Air communication

4.2.1. AVL (Automatic Vehicle Location)

For the AVL window of KAS-20C, the dispatcher can display icons of the mobile stations on the map and manage the operation status of the mobile stations. Selecting the mobile station from the map or Radio Resource List displays various menu (voice calls, sending a text message or special commands such as a remote control, viewing the communication log, etc.) regarding the selected mobile station.

KAS-20C supports OpenStreetMap, Scanned Map, or Google Earth. GeoJSON and KML files can be overlapped as layers on the map.

Receiving an Alert or Emergency from mobile stations, the icon is highlighted by striking color and received messages are listed on the log grid.

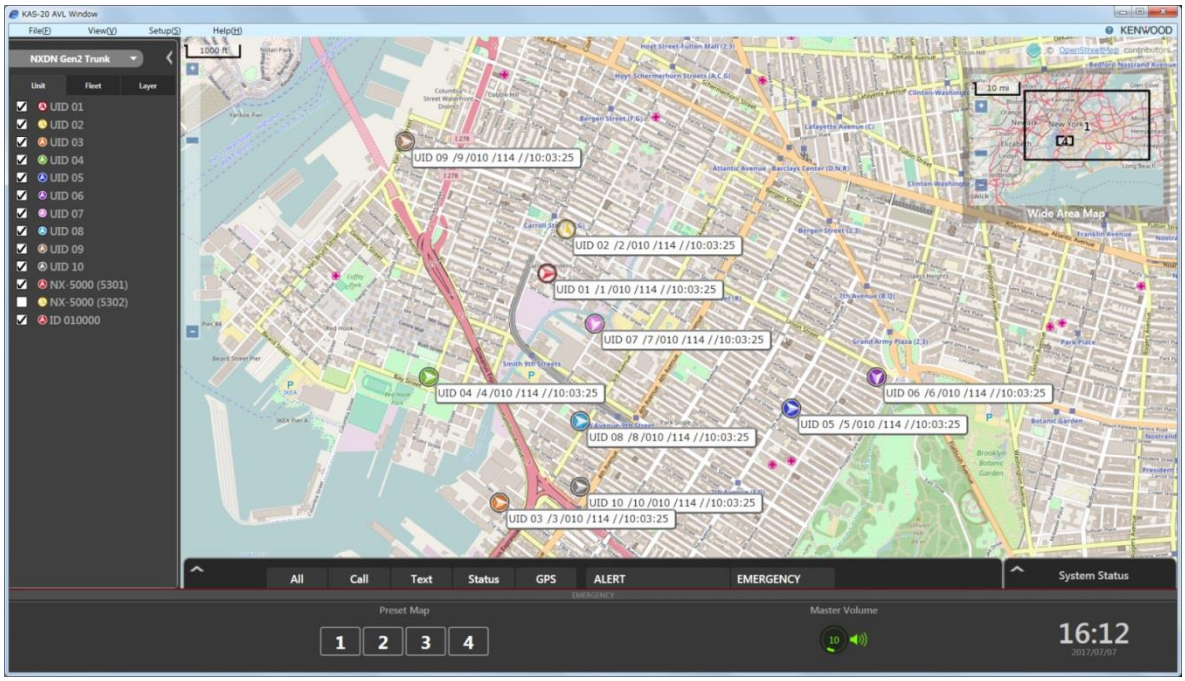


Figure 4-7 KAS-20/ AVL Display Example

4.2.2. Dispatch

KAS-20C Dispatch window is designed for the simple operation of All Call, Group Call, Individual Call etc. to mobile stations. Each mobile station is placed as a tile which can configure the color or size.

Using KAS-20C can create a temporary talk group even if a group which is not registered with the mobile station.

For the IP network connection, KAS-20C can forward the received voice to other mobile station registered in the same Patch Group. Patch Group can be created with KAS-20C.

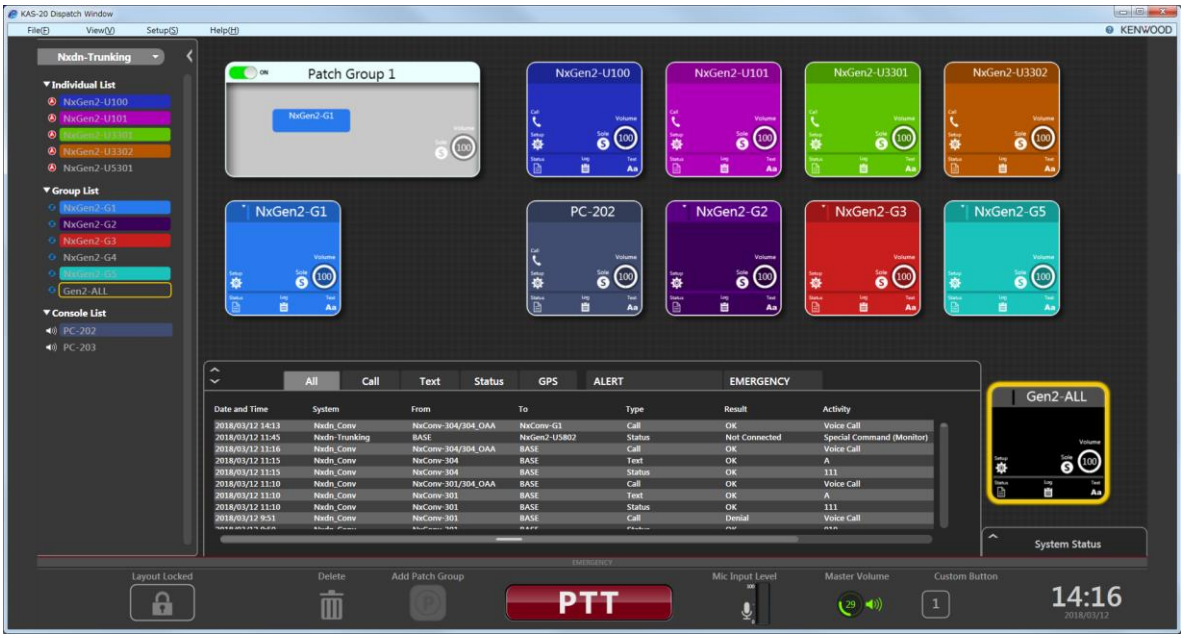


Figure 4-8 KAS-20/ Dispatch Display Example

4.3. Over-the-Air Programming (KPG-180AP)

For NX-3000/5000 series, the configuration data created by a programing software can be written to the radio through an IP network or air communication. This feature benefits for updating radios which have been working in a field, because bringing them to the location of PC does not need. To write a configuration data via IP network or air communication, uses the PC software named KPG-180AP, OTAP (Over-The-Air-Programming) Manager.

IP Network Connection

OTAP Manager can contact to a radio system without IP Gateway (KPG-1013GW), but only one software is available in this case.

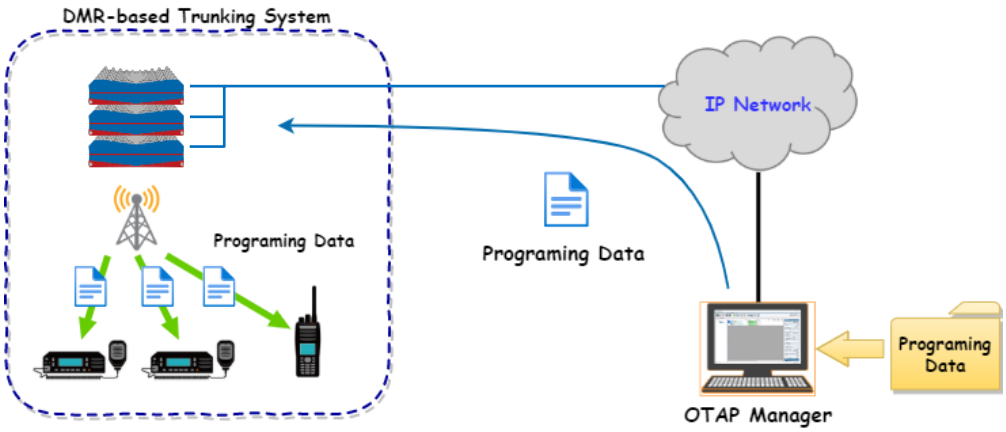


Figure 4-9 IP Network Connection

By using IP Gateway (KPG-1013GW), multiple OTAP Managers can contact to a radio system.

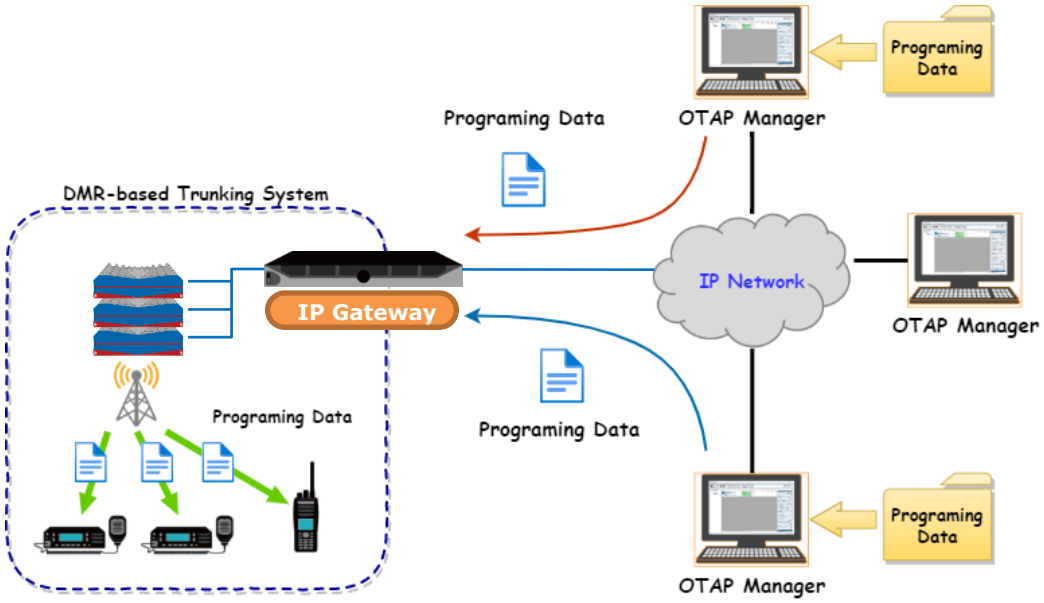


Figure 4-10 IP Network Connection / IP Gateway

DMR Air Communication

OTAP Manager can contact to a radio system by DMR air communication. A base radio connected to PC by a serial interface is required in this case, and it communicates with a radio system as a terminal.

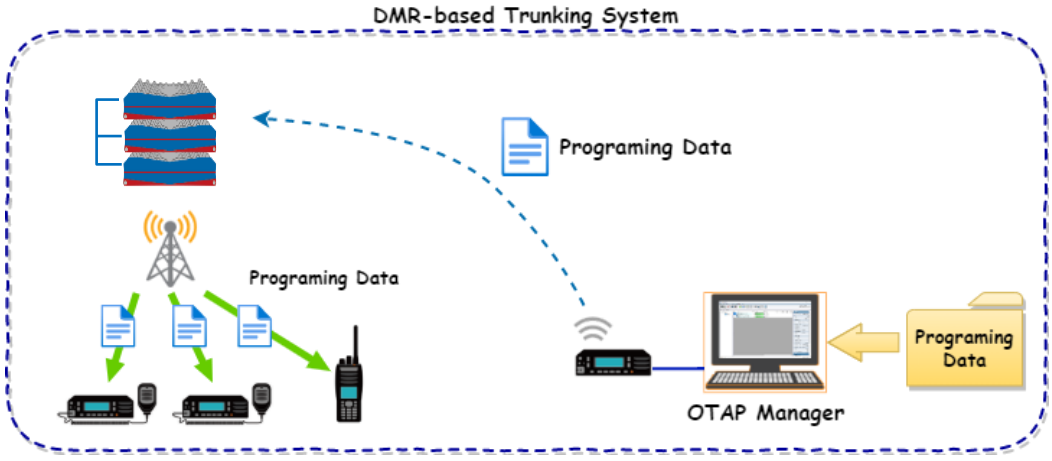


Figure 4-11 DMR Air communication

Overwrite Password

The Overwrite Password function of the programing software is also available using the OTAP manager. Invalid writing can be prevented by a password.

Configuring the date and time to send data

On the scheduled date and time, the OTAP manager can send data to multiple radios by batch processing. This function is useful because the schedule of updating radios can be set beforehand.

Optimization of data to send

The OTAP manager judges automatically whether writing all data is needed or writing only the difference data is efficient, and it sends optimized data to radios.

Reactivation

A radio must reactivate to apply the data received from OTAP manager. The timing of the radio's reactivation can be select from the following and can be indicated to radios by OTAP manager.

- By rebooting forcefully after writing the data
- By turning power-off and then on again after writing the data
- By operating the programmable button after writing the data
- When a specified date and time comes after writing the data
- When the Reactivation command is received after writing the data

Log of sent data

Log of writing the configuration data can be viewed later. Log can also be output with csv file format. It is useful to record the information of the radio which has proceeded the writing successfully or unsuccessfully.

4.4. KAIROS Manager

To set up and manage KAIROS series needs to use the PC application software, named KAIROS Manager, working on a Windows based system. KAIROS Manager accesses to a repeater via LAN cable directly or through the IP network. The followings are main functions provided by KAIROS Manager.

- Firmware writing
- Parameter settings for Network Configuration
- Parameter settings for Channel Configuration
- Parameter settings for Repeater Mode Configuration
- Parameter settings for the Synchronization among repeaters
- Remote monitoring of a repeater status
- Reboot or Shutdown a repeater remotely

KAIROS Manager can control users by password. It can be worked on a poorly performing PC because of it's a very light-weight program.

Figure 4-12 KAIROS Manager

4.5. KAIROS Web Interface

KAIROS Web Interface is a web application tool which can be operated from a browser (Firefox) through HTTP. This tool is opened by accessing to a repeater via IP, and it can set up and manage a repeater as same as KAIROS Manager, in addition, the following functions are provided by KAIROS Web Interface.

- Monitoring or controlling voice calls or text messages as a simple console
- Checking installed software licenses
- Obtaining a code to request software licenses
- Activating software licenses
- Running, stopping or removing Trunking System Controller (TSC)

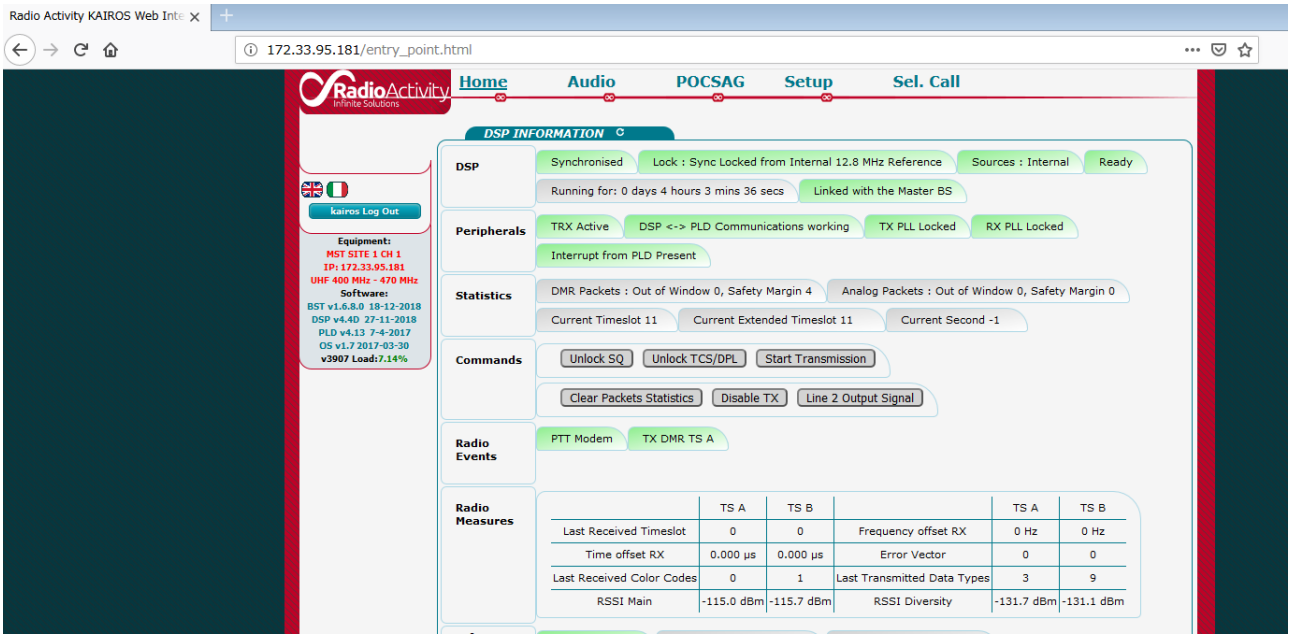


Figure 4-13 KAIROS Web Interface

4.6. KAIROS Network Management System (KA-NMS)

KAIROS Network Management System (KA-NMS) is a web application tool which can be operated from a browser (Firefox) through HTTP. This tool is opened by accessing to Trunking System Controller (TSC) via IP, and the followings are main functions provided by KA-NMS.

- Parameter settings for DMR-based Trunking System Configuration
- Registering radio's information by associating with Individual ID
- Registering talk groups information
- Registering external tools information
- Remote monitoring of a system status

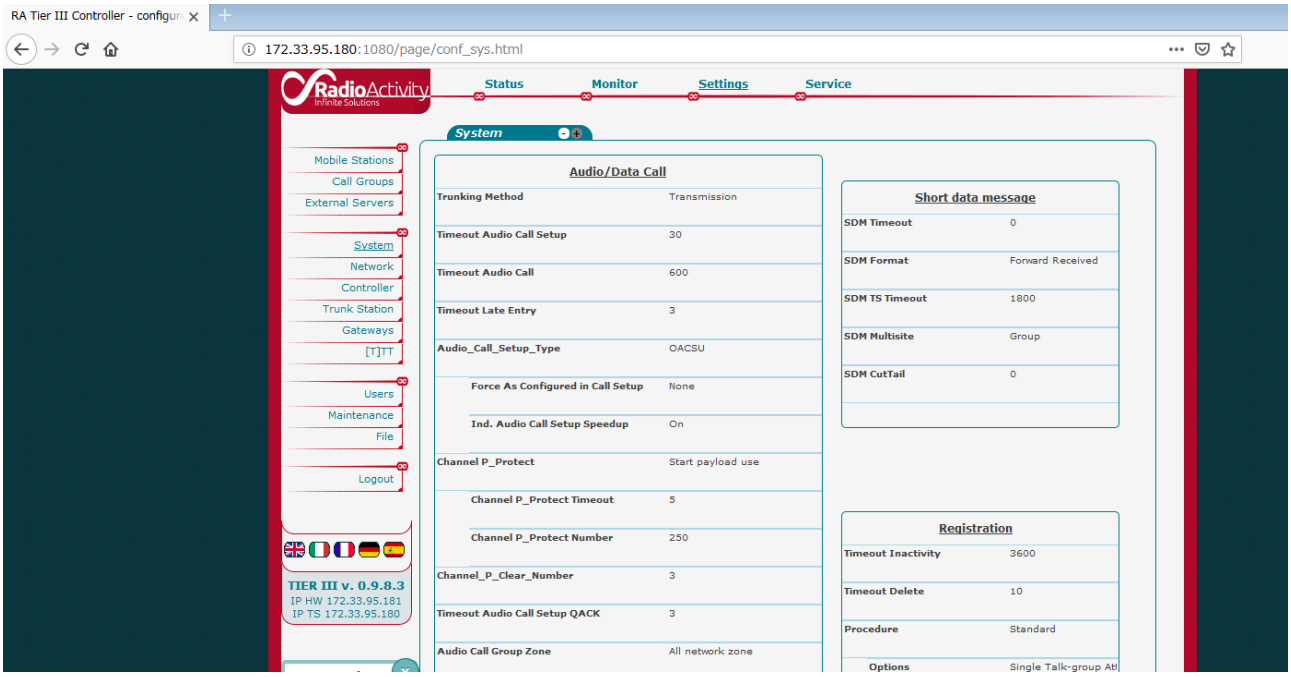


Figure 4-14 KAIROS Network Management System (KA-NMS)

4.7. KAIROS NetControl

KAIROS NetControl is a Windows based application software that can monitor a status of KAIROS series connected via IP network. These statuses are displayed on the application by polling each repeater in regular intervals.

One of the most important concerns is that the system operates 100% at all the time. By using KAIROS NetControl, a system operator does not need to go to the location of the repeater to check the repeater's condition. If an error such as abnormal power supply voltage or abnormality of temperature occurs, a system operator can know what kind of abnormality occurred in which repeater of which site by warning indications.

Failure status logs are saved as files automatically, and the log can be load and read by KAIROS NetControl anytime.

Figure 4-15 KAIROS NetControl

4.8. Development Tools

JVCKENWOOD provides the software development kits for system integrators or local solution developers. By using the kits, many software such as special console, dispatching, position management or voice logging tools can be developed quickly, and it doesn't need to spend much time to investigate specific protocols.

4.8.1. PC Interface Protocol

A radio unit has a serial data interface. The protocol of data communication is Kenwood original, called PC Interface Protocol, and it includes several control commands and information commands. JVCKENWOOD provides the document that describes the format of commands and how to use PC Interface Protocol.

4.8.2. Application Interface Specification (AIS)

Dispatch applications can connect the DMR-based Trunking system over IP network through IP Gateway (KPG-1013GW), and Application Interface Specification (AIS) defines the IP protocol between them. JVCKENWOOD provides the document that describes the details of AIS.

4.8.3. Voice Logging Interface (VLI)

Voice Logger tools can connect the DMR-base Trunking system over IP network through IP Gateway (KPG-1013GW), and Voice Logging Interface (VLI) defines the interface between them. JVCKENWOOD provides the document that describes the details of VLI.

4.8.4. Software Development Kit (KPT-111SDK)

KPT-111SDK is a software development kit that includes sample programing codes and help files to help users develop Microsoft Windows applications such as Dispatch Software and AVL Software. The sample programs are designed for communicating with DMR-based Trunking system through IP Gateway using the AIS. Use of the KPT-111SDK reduces the amount of code and time required in writing the AIS protocol, thus it makes development easier and less time consuming, decreasing time-to-market.

4.8.5. SNMP

The equipment of DMR-based Trunking system has supported the Simple Network Management Protocol (SNMP) interface, and a system operator can collect and organize the working situation of that devices.

4.8.5.1. KAIROS series

KAIROS series supports Trap notification, the destination IP Address and Port of the notification can be configured by KAIROS Manager. By using KAIROS NetControl, a system

operator can monitor the working situation of KAIROS series.

4.8.5.2. IP Gateway (KPG-1013GW)

KPG-1013GW supports Polling information and Trap notification, the destination IP Address of Trap notification can be configured by the web interface of KPG-1013GW. By using general-market SNMP manager, a system operator can monitor the working situation of KPG-1013GW.

4.9. Down Time

A system might have a downtime when the system or each site configuration is changed, or repeater's software is changed. Downtime is triggered by writing a data to targeted repeater and rebooting it.

KAIROS series

For KAIROS series, a system remains on work while the data is uploading. KAIROS reboots after completing the upload. Time to reboot is various depending on the data uploaded. Rebooting will spend a few minutes.