THE STUDY ON THE EFFECT OF SHORT DATA MESSAGE SERVICE ON CONTROL CHANNEL IN MPT1327 TRUNKED RADIO NETWORK

by

Mr. Somkiat Zunlai

A Final Report of the Three - Credit Course
CE 6998 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
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Project Title	The Study on the Effect of Short Data Message Service on Control Channel in MPT1327 Trunked Radio Network
Name	Mr. Somkiat Zunlai
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Academic Year	November 2001

The Graduate School of Assumption University has approved this final report of the three-credit course. CE 6998 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

Short Data Message (SDM) has been used worldwide in MPT1327 trunked radio network. Presently, there are many applications of Short Data Message such as Remote Monitoring and Automatic Vehicle Location System (AVLS). Short Data Messages is transferred on the control channel, sharing load with signaling traffic of voice call. When the demand for Short Data Message is increased, SDM may impact the relative loading both incoming and outgoing. Therefore, the effect of Short Data Messages on the control channel load in MPT1327 trunked radio network is studied. The parameters that are used to investigate into these effects are relative incoming load and relative outgoing load.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude to my advisor, Dr. Sudhiporn Patumtaewapibal, for his advises, guidance and encouragement during this thesis study.

I would like to acknowledge Mr. Wallop Saenyanan and Mr. Supa-ut Wongsukon from United Communication Industry (WorldRadio) for their suggestions, discussions and supporting information during my project study.

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I. INTRODUCTION

1.1 Background

The trunking principle ensures efficient use of available radio channels. Trunking means that a common pool of radio channel can be shared among many user groups, even by several user organizations, enabling effective use of radio frequencies and other system resources.

The basic communication requirement of typical trunked radio user differs clearly from those of cellular users:

(1) Cost-effective organization internal communication

(2) Fleet management

(3) Internal communication of work groups

(4) Emergencies and incident handling

(5) Reliable and dependable communication

Typical trunked radio user organization includes the following:

(1) Public trunking operators

(2) Energy production and distribution

(3) Authorities (police, ambulance, fire brigade)

(4) Communal utilities

(5) Public transport

(6) Construction and maintenance

(7) Industrial plants

(8) Airport and harbors

MPT1327 is the most widely accepted open trunked radio standard in the world. It defines an open air-interface in trunked radio systems. Thus, it enables the use of radio units from several suppliers in the same systems. MPT1327 is suitable for both public and private network applications, starting from small local systems to nation wide networks. The choice of VHF and UHF frequency band is also free, ranging from 80MHz to 800 MHz.

Data message service in MPT1327 trunked radio system means sending either numerical status messages or text messages between various radio and fixed subscribers. Typical mobile data equipment includes alphanumeric displays, printer and personal computer. With these facilities, radio unit can exchange information system-wide with dispatchers, other radio units, mainframe computers or public data network services. Typical applications in private network are computerized dispatching, automatic vehicle location with GPS receivers, and automatic telemetry systems.

From aspect of the signaling traffic loading, standard MPT1327 data messages are often a more effective way of dispatching than speech call because they are transmitted on control channel and do not reserve any traffic channels. From the user aspect text messages are a convenient way of issuing addresses and work details, especially if the called person is driving or absent from the vehicle at the moment.

1.2 Statement of the Problem

The amount of signaling traffic of radio unit in MPT1327 network depends on the main activity of user. The main activities of user are call set-up, registration and short data message.

Normally when launching the short data message services in MPT1327 network, the number of signaling messages tends to be increased. Therefore, if the amount of short data message from the radio unit is increased, that means the radio unit will reserve control channel for a long time. Thus, the other signaling requests from other radio unit may be blocked. The delay of signaling message may be increased as well because of sharing control channel together between signaling message of voice service and short data message service.

1.3 Objectives

(1) To investigate relative load on control channel by varying the number of short data message calls via simulation approach.

(2) To create the control channel load monitoring software for network operator.

1.4 Scopes and Limitations

(1) MPT1327 trunked radio network for this study is ACTIONET from NOKIA Company.

(2) ACTIONET network is studied covering only one base station, one mobile exchange and one system exchange.

(3) System exchange comprises of one mobile exchange, seven-registration areas and a registration area consists of 4 base stations. These are assumed to find the arrival rate of registration update in the simulation.

(4) Registration update is considered only one base station at the boundary of registration area.

(5) No errors are in transmission.

(6) The length of information part or signaling message lengths to MPT or ETSI standard.

(7) All subscriber terminated calls are answered by users.

II. ANALOG TRUNKED RADIO SYSTEMS

2.1 MPT1327

(1) MPT1327 Trunking Protocol Overview

MPT1327 is a radio trunking protocol that is widely used everywhere in the world apart from North America. MPT is a United Kingdom acronym for the Ministry of Post and Telecommunications. MPT1327 defines the network protocol between radios and Trunking System Controllers (TSCs). MPT1327 is a trunking protocol that defines the radio interface between a TSC and a radio. In other words, it's a rule book for how radios and TSCs are allowed to behave and interact with each other.

What Services Does It Provide?

(a) Voice calls: Radio, radio group, wired subscriber, PABX (Private Automatic Branch Exchange) and PSTN (Public Switched Telephone Network) subscribers

(b) Data calls: LAN terminals, radio data equipment

(c) Emergency calls: Radio, radio group, wired subscriber, PABX and PSTN subscribers

(d) Include calls: Radio, radio group, wired subscriber, PABX and PSTN subscribers

(e) Status messages: Radio, radio group, LAN terminals

(f) Short data messages: Radio, radio group, LAN terminals

(2) How Does It Work?

The radio system continuously sends out packets or telegrams of information over a control channel. The number of slots per frame depends on the infrastructure. There is one telegram per slot.

The radio monitors and responds to telegrams addressed to it or its group on the control channel. Control channels may be continuous or time domain multiplexed (TDM) over a number of sites, where a site is the coverage area of a specific channel.

(a) Random Access Slotted Frame

MPT1327 is essentially a random access slotted frame protocol. The Figure 2.1 on this page illustrates a random access slotted frame protocol. Each frame consists of a number of slots (in this case seven). Each slot contains a single telegram and control channel related data.

To understand random access, refer to the following call scenario.

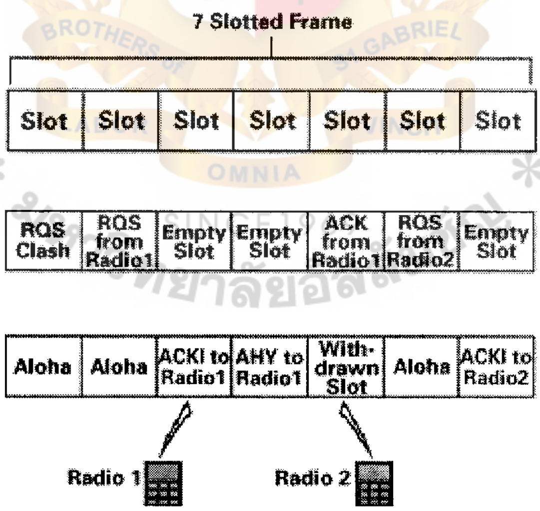


Figure 2.1. A Random Access Slotted Frame Protocol.

(1) Radio 1 and Radio 2 both send out a Request for Speech (RQS) in the first slot. The telegrams clash and are not seen by the TSC.

(2) Both radios wait a random number of slots and retry the request. In this case Radio 1 manages to successfully transmit in the next slot.

(3) The TSC sees this and returns an ACKI (Intermediate Acknowledgment).

(4) The TSC checks whether the radio is alive by sending an AHY (Ahoy) telegram to Radio 1. In doing this, the TSC withdraws the next slot so only RADIO 1 can transmit in it.

(5) Radio 1 responds with an ACK (Acknowledgment) in the next slot.

(6) Radio 2 finally decides to retry sending a RQS 5 slots after the clash. The RQS does not clash this time and is acknowledged by the TSC in the next slot by an ACKI.

(b) Time Division Multiplex (TDM)

The Figure 2.2 shows a map of geographical coverage of a three-site TDM system. The control channel is synchronized so that Site 1 transmits a frame, Site 2 transmits a frame, Site 3 transmits a frame, then Site 1 transmits a frame again, and so on. The Figure 2.3 is an example of what a radio sees as it moves from position A to position E via B, C and D. Refer to the Figure 2.2.

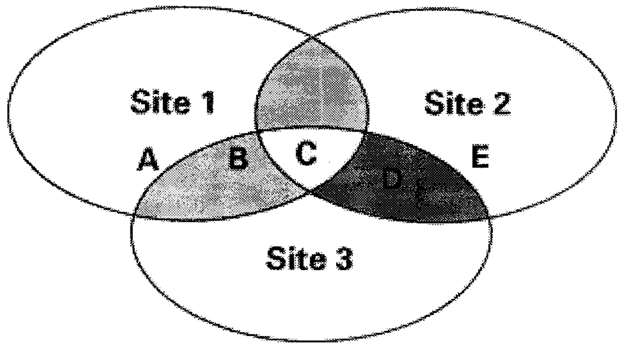


Figure 2.2. A Map of Geographical Coverage of a Three-site.

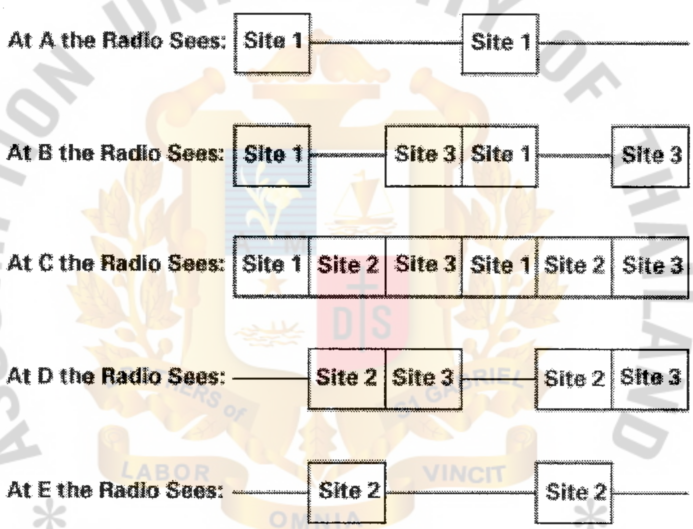


Figure 2.3. An Example of Radio Moves within Three-site Coverage.

At A, the radio can see only Site 1, so it sees only one frame for every three available. Refer to the following figure.

At B, the radio can now see Site 1 and Site 3 but it is not yet within the coverage range of Site 2.

At C, the radio can now see all three sites and the channel appears to be continuous.

At D, the radio moves out of the coverage area for Site 1 and now sees two frames for every three from Sites 2 and 3.

Finally at E, the radio now only sees Site 2, so it sees one frame for every three available.

(c) A Call Scenario

The following scenario demonstrates how a speech call is set up between Radio A and Radio B using some standard telegrams:

(1) User of Radio A dials in Radio B's address.

(2) Radio A to TSC: RQS (Request for Speech)--"Can I talk to radio B?"

(3) TSC to Radio A: ACKI (Intermediate Acknowledgment)--"Shut up and hang on!"

(4) TSC to Radio A: AHYC (ESN Inquiry)--"What's your electronic security number?"

(5) Radio A to TSC: SAMIS--"Here's my electronic security number."

(6) TSC to Radio A: AHY (AHOY!!!)--"Are you still there Radio A?"

(7) Radio A to TSC: ACK (Acknowledgment)--"Here I am."

(8) TSC to Radio B: AHY (AHOY!!!)--"Are you and your user there Radio B?"

(9) Radio B to TSC: ACKI (Intermediate Acknowledgment)--"I am, I'll check to see if my user is around."--Radio starts ringing.

(10) Radio B to TSC: RQQ (Status - 31- Status message)--Radio user B has just pressed his "Press To Talk" (PTT) button--Radio B: "He's there!"

(11) TSC to Radio B: ACK (Acknowledgment)--"OK thanks for telling me he's there."

(12) TSC to Radio A: ACKQ (Queue acknowledgment)--"I've got no free channels so I'm putting you on a queue Radio A." Radio A displays "Call Queued."

(13) Radio B receives no call progress information in the five seconds after telling the TSC that its radio user was awake. Radio B displays "Call Queued."

(14) TSC to Radio A: GTC (Go to traffic channel)--"OK! Here's your channel Radio A."

(15) TSC to Radio B: GTC (Go to traffic channel)--"OK! Here's your channel Radio B."

(16) Users of Radios A and B can now talk to each other on their newly allocated traffic channel.

(17) Radio A to TSC: MAINT (DISCONNECT-Call maintenance radio disconnect message)--Radio A user has just hung up.

(18) Radio A go back and monitors the control channel.

(19) TSC to Radio B: CLEAR (Clear the traffic channel)--"Get off this channel."

(20) Radio B go back and monitors the control channel.

2.2 Logic Trunked Radio (LTR)

(1) Trunking Method Comparison

There are two different methods currently being used to control trunking systems. One is distributed control used by LTR, and the other is dedicated control channel used by Motorola and some other systems.

The dedicated method has several disadvantages over the distributed method. One disadvantage may be throughput constraint. When a dedicated control channel is used, all access must be made through the control channel. Therefore, some method must be used to avoid collisions. Most systems use a modified version of slotted (aloha) access control. The characteristics of this system are well documented in other literature. The maximum throughput of slotted access control is approximately 37%. This results in throughput constraint even though the control channel packets are typically short in duration. Other disadvantages are that a control channel system must process all calls in sequential order, and as loading increases and fewer channels are available, accesses rise exponentially and radios must compete with each other on only one channel.

One advantage of the distributed method used in LTR systems is that access can be made on any channel that is idle. Each repeater determines which channels are idle and transmits this information in a data stream that coexists with voice information. This means that each repeater maintains its own data stream and handles all accesses on its channel. Collision avoidance is handled by the radios. This provides full parallel processing of calls.

Another advantage of the distributed method is that it uses all channels for voice communications. With a dedicated control channel system, the control channel typically cannot be used for voice communications. In Figure 2.4, the blocking rates of five-channel systems are compared to those of a four-channel system (one channel used for control). It can be seen that there is significantly less blocking for the five-channel system. For example, at 57% loading, the five-channel system is blocked 20% of the time compared to 25% for the four-channel system.

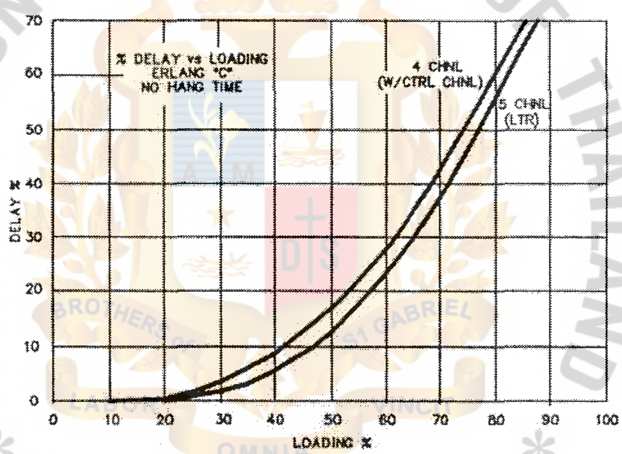


Figure 2.4. Blocking Rate Comparison.

Once a call is blocked, the waiting time is directly related to the blocking rate and the traffic loading. Therefore, a five-channel (distributed) system also has less waiting time. As shown in Figure 2.5, the waiting time for the five-channel system with a traffic load of 57% is 0.45 seconds compared to 0.71 seconds for the four-channel system using a control channel.

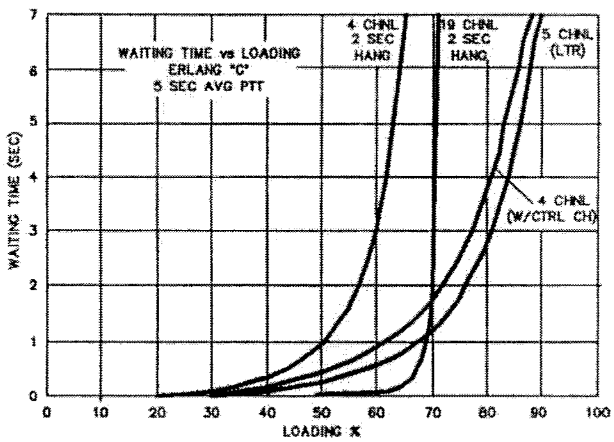


Figure 2.5. Waiting Time vs Loading.

(2) Radio and Repeater Description

(a) General Radio Information

The radio transceivers used in an LTR system must be programmed for LTR signaling and also be of the correct frequency range (800 or 900 MHz). Operation of an LTR transceiver is even simpler than with conventional operation. The reason is that many functions normally performed by the user are performed by the control logic such as channel selection and monitoring before transmitting. All the user has to do to make a call is to select the desired system (and group if applicable) and press the push-to-talk switch. If a busy signal or out-of-range condition is not indicated by special tones or warning messages in some displays, the path is complete and speaking can begin.

The basic transceiver controls include power on-off, volume control and system select. Most transceivers also have a group select switch. There is no squelch control because the squelch is internally preset.

(b) General Repeater Information

Repeaters operate on a single frequency, so one repeater is required for each channel. A controller card in each repeater performs all control and signaling functions on that channel. Information is exchanged between repeaters via a high-speed data bus. A separate system controller is not required. Optional accessories such as Telephone Interconnect Card and ID Validator may be used.

(c) Home Repeaters

All radios have one of the site repeaters assigned as its "home" repeater. This is the repeater from which it receives most of its control information. When a radio is not placing or receiving a call, it is always monitoring its home repeater to determine which channel is free and if it is being called by another radio.

The home repeater is always used to make a call unless it is busy. If the home repeater is busy, any other repeater in the site may be used. Up to 250 ID codes are assigned to each repeater. An ID code and home repeater number are the "address" of radios in the system. Therefore, up to 1250 separate addresses can be assigned in a five-repeater system and up to 5000 can be assigned in a twenty-repeater system. An ID code may be assigned to an individual radio or group of radios as required.

2.3 SmarTrunk

(1) System description

It has taken a long time for the spectrum efficiencies of trunking to reach the 450 MHz band. Now that people are beginning to trunk their community repeaters and private campus systems, SmarTrunk II offers an economical and efficient way to accomplish this.

SmarTrunk II is an overlay system, which means that in many cases the system can be installed with your existing two-way radio system. This means you may not have to buy new radios or repeaters to achieve the benefits of trunking. A SmarTrunk II system requires a SmarTrunk II controller connected to each repeater and a mobile logic board installed in each mobile or portable radio in the system. SmarTrunk II will accommodate up to 16 channels, which may be gradually added as your system expands. Required for SmarTrunk II operation, customized logic boards are available for a variety of brands and models of popular mobile and portable transceivers. In many cases, the SmarTrunk II logic board simply plugs into the radio for easy installation. SmarTrunk II allows you to trunk your repeaters together for more efficient use in either a dispatch-only mode or a combination of dispatch and telephone interconnect service. If you choose the combination mode, you can limit telephone access to only certain mobiles while denying access to other mobiles. You can further limit those mobiles with telephone access to local calls only or you can allow certain mobiles access to toll calls or long distance calls. The SmarTrunk II system keeps track of all calls that are made on the system, whether they are radio dispatch calls or telephone calls. It records both incoming calls and outgoing calls. It does this through call accounting records which record the date, time, type of call, number being called and the number of the mobile subscriber who is initiating the call. The call accounting records provide the data for air time billing.

(2) System security and privacy

Each mobile subscriber is assigned a confidential paging code which is transmitted via a proprietary, digital signaling protocol. To allow any mobile to work on the SmarTrunk II system, this paging code must be installed into the memory of the trunking controller. Without it, a mobile is not allowed access to the system. This feature will prevent the system pirates who, once they have a CTCSS tone, can add mobiles to their fleet and not advise the system operator. Privacy on the system is one of the key features of SmarTrunk II. Once a mobile has acquired a channel, only the mobiles that have been called can hear the conversation. Other mobiles cannot gain access to the channel to hear any of the conversation. This applies whether the call is a dispatch call or telephone call.

(3) System versatility

System versatility is an important feature, especially for private system users. In a typical private system, you may have many levels of mobile operators--from the worker at the job site to the boss in the office. Typically, some system features are desired for the managers and not for all the workers. To take advantage of all of the system features, a radio with a DTMF keypad installed is required. This allows mobile to mobile selective calling and or telephone calling. However, in many cases, these kinds of features are not required by all system mobile users. The SmarTrunk II system allows for this with its PTT (Push to Talk) group call feature. With this feature the mobile operator only needs to push the talk button on the radio and all the mobiles in that radio users group will be contacted. This user friendly feature does not require the radio to have a DTMF keypad installed.

2.4 SmartNet

In the decade since the trunked radio first appeared, different manufacturers have taken different approaches in the design of their trunked systems. Motorola's approach to trunked radio systems offers many advantages over competitive systems. We'll begin with a user organization, since one of the key benefits of trunking is the way in which customers can organize their users. Most two-way radio users are organized into various fleets and talk groups (sometimes referred to as sub-fleets) as shown in the following figure.

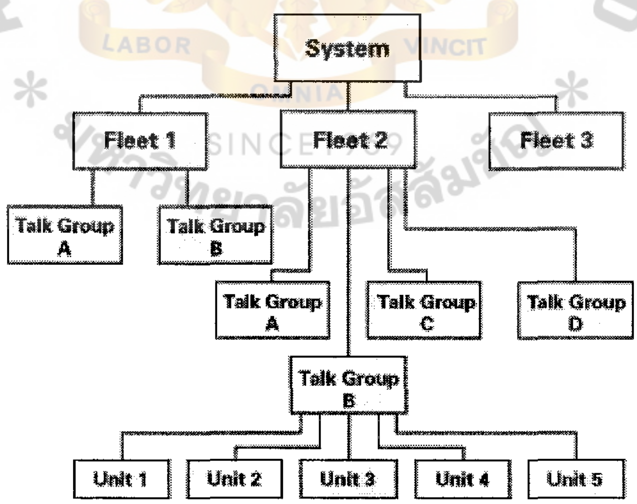


Figure 2.6. Fleet and Talkgroup.

(1) A fleet is usually a group of radio users with a common functional responsibility, such as a public works department.

(2) A talk group is a subset of a given fleet, whose normal communications do not require interface with other subsets of the fleet, such as the maintenance department within the public works department. Talk groups are made up of individual users. Typically, the majority of an individual's communication requirements will be within his or her own talk group.

In conventional two-way radio, talk groups are created by assigning a different frequency to each group. For example, a municipality may have separate repeaters on different frequencies for its police, fire, and public works departments. In conventional two-way radio, only users with very large systems can afford to devote separate channels for each talk group.

Trunking provides a much more economical means of organizing talk groups, which you will see later. But first, let's see exactly what a trunking system is and how it works. Through a series of diagrams, let's assemble a Motorola trunked system. The system begins with a component that should be familiar to you, a typical repeater, as shown in the following figure.

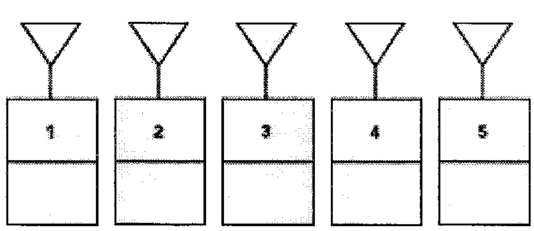


Figure 2.7. A Typical Repeater.

The backbone of Motorola's trunked radio system begins with a series of trunked repeaters located at a prime site to assure optimum coverage. While five repeaters are shown, it is possible for trunked systems to have up to 28 repeaters. We'll limit our examples to five to simplify the explanation.

An important thing to remember about trunked repeaters is that each repeater is capable of handling data words, and voice traffic. In fact, in a Motorola system, one repeater is always assigned the duty of transmitting and receiving the data required to keep the system functioning. When a repeater is performing this duty, it is called the control channel to distinguish it the other repeaters, which are designated as voice channels. A heavy load is placed on the control channel because it is continuously transmitting and receiving data. To even out this load, control channel duty is automatically changed to another repeater every 24 hours. Four repeaters in any one system can be used (one at a time) for control channel duty. This redundancy ensures that your customer's system will continue to operate in the trunked mode in the unlikely event of a control channel repeater failure. The Motorola trunked radio system uses a central controller as shown in the following figure.

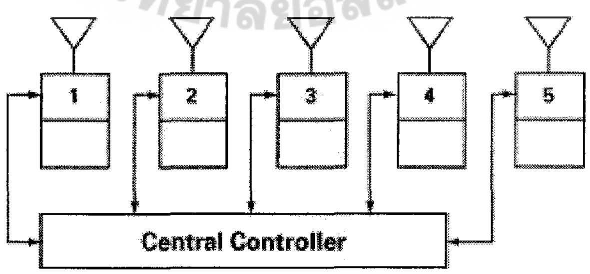


Figure 2.8. The Motorola Trunked Radio System.

All Motorola trunked systems use a dedicated control channel which monitors and optimizes system operation according to the customer needs. Other systems do not use a dedicated control channel. Instead they use a distributed logic system which provides voice and data on the same channels. Because Motorola trunked systems have a dedicated control channel, they can provide customers with the following advantages:

(1) True priority control, first-in, first-out with priority.

(2) Conversation continuity on busy systems.

(3) Recent user priority.

(4) Automatic queuing across priority levels.

(5) Automatic callback.

(6) Fast, reliable, immediate emergencies access without the need to dedicate a channel to emergency use.

Now that the backbone is in place, let's add some system users. Figure 2.9 shows several organizations making use of this trunked radio system. Each organization consists of a control station at the dispatch point and a mixture of mobile and portable radios. All of these trunked radios are synthesized and capable of switching to the frequencies of any of the repeaters in the system. They also contain a unique code word that identifies each unit to the backbone and indicates to which talk group it belongs.

Now that you have been introduced to all of the pieces of the trunking system, the best way to understand how those pieces work together is to follow a typical call sequence from the moment before access is requested until the conversation is completed. Figure 2.10 represents a trunking system as it would appear in the idle mode, and shows repeater1 as the designated control channel. When the system is in the idle mode, no subscribers are talking and all their radios are monitoring the control channel, which, in this case, has been assigned to repeater1.

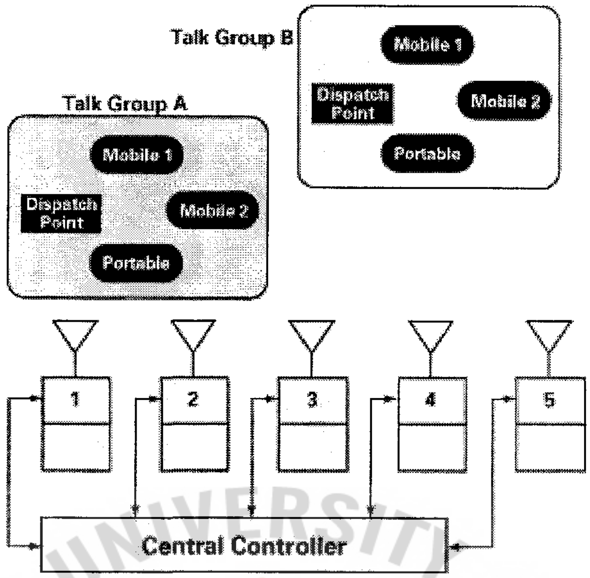


Figure 2.9. Talkgroup Concept.

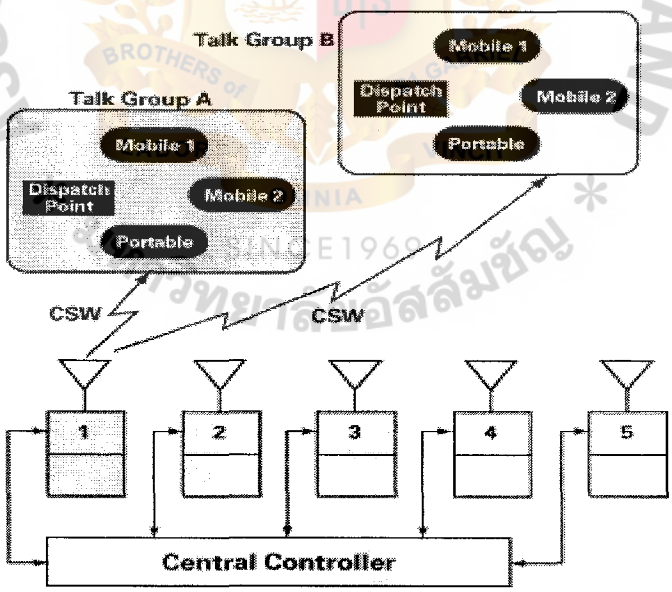


Figure 2.10. The SmartNet System in the Idle Mode.

The radio speakers are muted since the transmissions received are in the form of data. Because of this patented feature, trunked radios do not need coded squelch to give the individual operators a quiet communication environment. This means ease of use for operators.

During the idle mode, the central controller is constantly sending out, via the control channel, data signals called the Outbound Signal Word (OSW). The OSW is received by all the user radios so they know which channel to monitor as the control channel. The central controller is also monitoring the control channel to see if anyone wants to make a call. All of this is done without operator involvement and within milliseconds. The following figure shows the dispatcher of Talk Group B initiating a request to access the system.

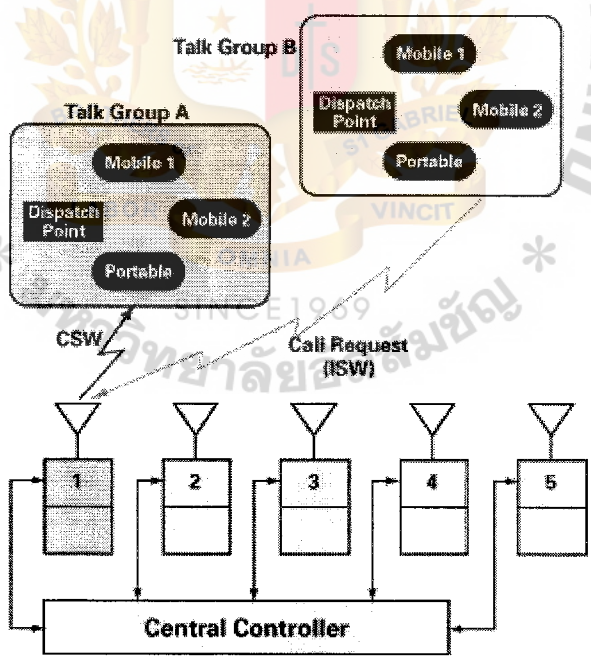


Figure 2.11. The Initiating a Request to Access the System.

When the microphone is keyed at the dispatch point, a burst of data, called the Inbound Signal Word (ISW), identifying the individual radio and its talk group, is automatically sent to the control channel. In less than half a second, the following occurs:

(1) The ISW is sent through the control channel to the central controller.

(2) The central controller processes the ISW and assigns one of the idle voice channels (in this case Repeater 5) to the entire talk group as shown in Figure 2.12.

(3) The command to switch to the frequency of the assigned voice channel is transmitted, in the form of another burst of data, back to the talk group's radios over the control channel.

(4) The radios in the talk group switch to the assigned voice channel automatically and in time to receive the dispatcher's first words, as shown in Figure 2.13.

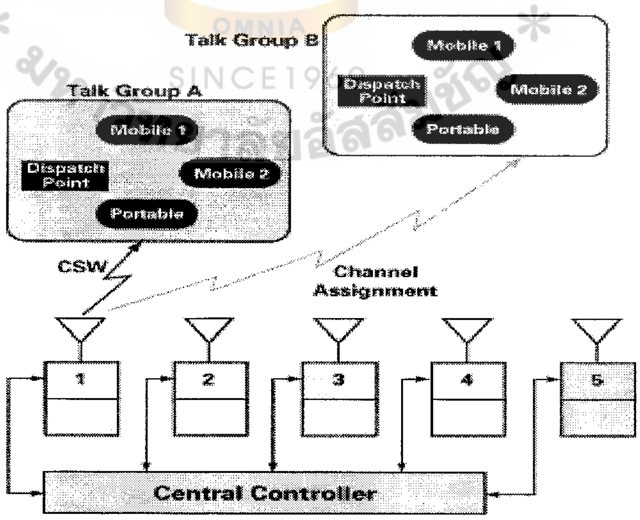


Figure 2.12. The Voice Channel Assignment.

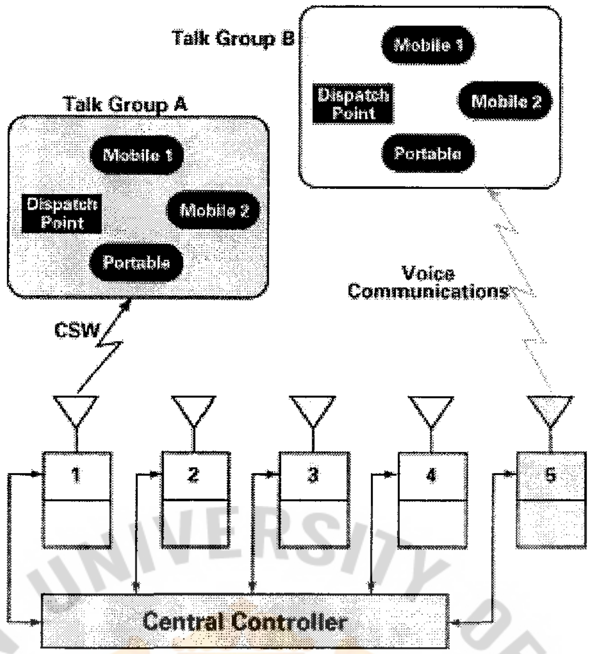


Figure 2.13. The Radio is Automatically Switched to the Assigned Voice Channel.

(5) Radios that are not members of the talk group ignore the data and continue to monitor the control channel.

(6) When the call is completed, the radios in the talk group switch back to the control channel frequency and once again continue to receive the data signals from the central controller. The events just described occur when a voice channel is available at the time the request for access is received by the central controller. But what happens during busy periods when there are no idle voice channels?

When a user tries to access the system and there are no available voice channels (all repeaters are in use), the following sequence of events occurs:

(1) The ISW is sent by the user radio requesting access, received by the control channel repeater, and sent to the central controller.

(2) The central controller processes the request for access and finds that there are no available voice channels, as shown in the following figure.

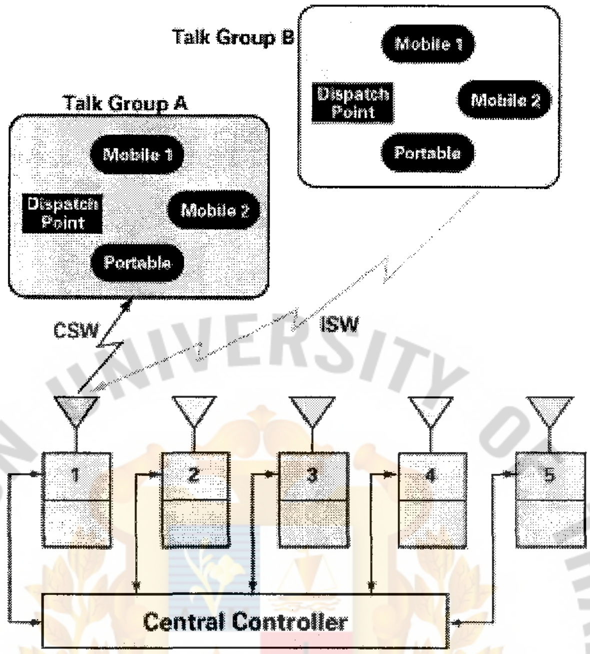


Figure 2.14. When There are No Available Voice Channels.

(3) The central controller notifies the caller, with an outbound data word, that the system is busy. Refer to the following figure. This causes a busy tone to be generated by the requesting radio. This tone is similar to the busy signal you receive on your telephone. But unlike your telephone, the central controller doesn't forget that you attempted to call.

(4) The access request is placed in a new user queue by the central controller where it remains until a voice channel becomes available.

(5) When a voice channel becomes available, the central controller sends another data word over the control channel, which is received by the radio in the new user queue.

(6) Refer to the following figure. The caller is notified with another tone, and all of the talk group radios are switched to the assigned voice channel.

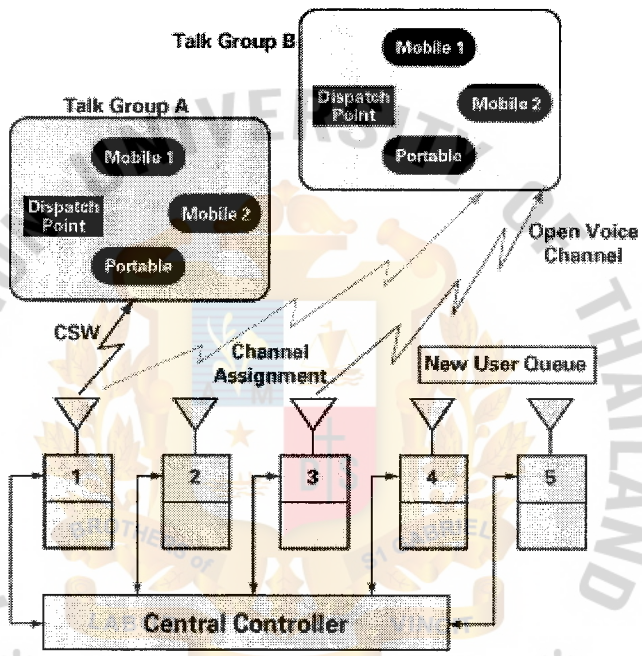


Figure 2.15. When a Voice Channel Becomes Available.

(7) When the call is completed, the radios in the talk group switch back to the control channel frequency and continue to receive the data signals from the central controller.

This type of new user queuing is referred to as FIFO (First-In, First-Out queuing). Consequently, if three callers are placed in the new user queue, the central controller remembers the order in which their requests for access were received and assigns available voice channels in that order.

The way Motorola trunking system "busy signals" are handled, means a caller need not continually re-key the microphone for system access. It also assures orderly access for all users.

III. DIGITAL TRUNKED RADIO SYSTEMS

3.1 iDEN (Integrated Dispatch Enhanced Network)

iDEN (Integrated Dispatch Enhanced Network) is functionally the same as MIRS (Motorola Integrated Radio System) except for difference in signaling characteristics. iDEN is a high-capacity digital trunked radio system providing integrated voice and data services to its users. The iDEN system uses M16-QAM digital modulation and VSELP (Vector Sum Excited Linear Predictor) speech coding techniques coupled with Time Division Multiple Access (TDMA) channel access methodology to enhance channel capacity and system services.

(1) System Characteristics

The following paragraphs highlight significant characteristics and features of iDEN digital trunked radio systems. In these descriptions, the term "fixed end system" refers to all infrastructure equipment, including base radio repeaters, site controllers and switching equipment. The term "mobile radio" is used as a general term referring to both mobile and portable radio equipment.

(2) TDMA/Channel Definition

Conventional trunking systems define a control or traffic channel by specifying a set of inbound and outbound frequencies to a user. The outbound frequency is the transmitter frequency of the base radio repeater, and the inbound frequency is the mobile radio transmitter frequency. In the iDEN system, a single inbound/outbound frequency pair is shared among six users through the creation and use of six 15-millisecond time slots. Each user transmits and receives during (and only during) one of the time slot intervals, so that the transmission from any given mobile radio is a pulsed

RF signal with a 1/6 duty cycle. The base radio is able to transmit and receive during any of the six time slots. Each mobile radio user is assigned a unique channel designation, which is defined by both a carrier number and a time slot definition. The carrier number specifies the inbound/ outbound frequency pair.

(3) M16-QAM Digital Modulation

The iDEN system uses M16-QAM modulation, a Motorola proprietary digital format utilizing M16-QAM modulation on four sub-carriers. This format involves both amplitude and phase modulation.

(4) Signal Formats Carrier Numbers vs. Frequencies

Three different signal formats are used in iDEN systems: iDEN, DJSMR, and DMCA. DJSMR and DMCA are international formats.
The frequency plan for domestic iDEN systems (i.e., those using the iDEN signal format) employs carrier numbers to designate channel frequencies. The relationships of carrier numbers to inbound and outbound frequencies are as follows:

(a) Inbound frequency (mobile transmit) = [(0.0125 x carrier number) + 806] MHz

(b) Outbound frequency (fixed end transmit) = [(0.0125 x carrier number) + 851]MHz

(5) Audio Digitization and Compression

Since iDEN is a digital trunking system, the audio coming from a user's microphone is digitized to produce a digital bit stream that becomes the modulating signal for the RF carrier. To make more efficient use of the channel, the digitized audio is compressed using a VSELP vocoder prior to being fed to the modulator.

(6) iDEN Mobile Operations

(a) Control Channel Acquisition

When first powered up, an iDEN mobile radio scans selected iDEN frequencies and locks on to the designated control channel. The control channel carries information continuously broadcast by the fixed end system regarding system identification and timing parameters for the mobile radio to use when it operates on the system. The control channel also defines the maximum transmit power that radios on the system may use.

(b) Mobile Synchronization

In its operational mode, the mobile radio aligns its frequency and transmits timing to the outbound signal received from the fixed end system.

(c) Mobile Registration

Each mobile radio in an iDEN system is identified by an international mobile station identifier (IMSI), which is assigned to it when it is first placed in service and performs an initial registration with the fixed end system. When making its registration request, the mobile radio supplies its international mobile equipment identifier (IMEI) to the fixed end system. After determining the validity of the IMEI, the fixed end station assigns an IMSI to the subscriber radio.

(d) Mobile Assisted Handovers

The assignment of an IMSI and dispatch IDs are important concepts in testing iDEN mobile radios, since a radio that has not been assigned appropriate IDs cannot place a dispatch or interconnect call. A radio that has not yet been placed in service, or one that has been subjected to a master reset since it was in service, will not contain IMSI and dispatch ID assignments When operating in a moving vehicle, an iDEN mobile radio can assist the fixed end system in determining when a handover to another cell should be executed. Whenever the mobile radio is not actually transmitting or receiving a signal from the fixed end system, it monitors outbound signals from neighboring cells and measures the received power and signal quality of these signals. When it determines that the signal from a neighboring cell is of higher quality than the signal from the fixed end system in its currently assigned cell, it transmits a handover request to the fixed end system. The iDEN infrastructure can also query a mobile radio for a measurement report. The mobile radio then transmits data back to the fixed end system indicating the received signal strength detected and measured by the mobile radio.

(e) iDEN Call Scenario

When a mobile radio places a call on an iDEN system, it goes through a series of system handshakes to establish the call. An example of an interconnect call follows:

(1) When the mobile radio is powered up, it scans and locks on to a control channel.

(2) The mobile radio registers on the system.

(3) When it initiates a call, the mobile radio places a service request on the control channel.

(4) The fixed end system assigns the mobile radio to dedicated control channel.

(5) The mobile radio uses the dedicated control channel to transmit the information required by the fixed end system to complete the call.

(6) The fixed end system assigns the mobile radio to a traffic channel to be used for communication of voice or data.

(f) iDEN Mobile Transmit Power Control

The maximum power to be transmitted by a mobile radio on the system is defined in the control channel system information. Under no circumstances will the mobile radio's transmitted power ever exceed this limit. However, the mobile radio does not always transmit at the maximum power allowed on the system. Each time it initiates or receives a call, the mobile radio determines the signal strength of its received signal. Based on this measurement and the power control constant defined on the control channel, it then adjusts its transmit power level to a level just high enough to ensure clear reception of its signal by its intended recipients.

3.2 TETRA

(1) What is TETRA?

TETRA = "TErrestrial Trunked RAdio" (Formerly: Trans European Trunked radio) TETRA is the new standard for digital trunked radio systems being developed by the European Telecommunications Standards Institute (ETSI). It has been designed to meet the demand for more efficient and flexible communication services from both private and public-access mobile radio users. It is able to address many of the technical and commercial problems of mobile radio system development into the 21st century.

As well as providing advanced and flexible system architecture, TETRA offers consistent voice quality, even greater call privacy, very fast call set-up, high speed data transfer and outstanding spectral efficiency.

(2) What is Digital Radio?

There is nothing mysterious about digital radio. "Digital" simply means that the signal which modulates the carrier is a stream of digital data. The information may have originated in analogue form such as speech, but it is converted into digital form prior to transmission. A lot of the complicated technology associated with digital radio is simply there to ensure the efficient transport of that data.

(3) Characteristics of TETRA Systems

(a) Fully digital

(b) Mixed voice and data communication

(c) Specified in open standards

(d) Makes efficient use of available spectrum (equivalent 6.25kHz channel occupancy)

(e) Allows internetworking with other communication networks via standard interfaces

(f) Extremely capable - supports a wide range of standard and supplementary communication services

(g) Integrated security (user/network authentication, air-interface encryption, end-to-end encryption)

(h) Supports wide area (inter-network) roaming

(i) Call handoff between cells

(j) A platform for a wide variety of mobile communication applications

(k) Network size: Local, Regional, National, International

(l) Virtual network environment allows an organization share a common physical network with others yet maintain privacy and have full control over their own communications functions

(m) Short data can be sent or received simultaneously with an ongoing speech call

(n) Effectively supports group working. Can manage group memberships over the network

(o) TETRA capacity: over 16 million identities per network; over 16 thousand networks per country.

(p) Direct Mode Operation (DMO) permits communication between mobiles without the network. DMO supports repeater and gateway functions to increase coverage

(q) Individual/group call setup time less than half a second (same cell)

(r) Priority mechanisms to guarantee access to the network

(s) Robust protocol designed to prevent crossed calls and other phenomenon resulting from unreliable propagation

(t) Independent allocation of uplinks and downlinks increases efficiency

(u) Network supports energy economy to improve mobile battery life

(v) Optional subscriber identity module (SIM card) for security keys and personal data

(w) User terminals may support multiple applications

(x) Bandwidth on-demand for increased efficiency

(4) Standard Interfaces

(a) Air Interface/Direct Mode Air Interface ensures interoperability of terminal equipment

(b) Terminal Equipment Interface permits the independent development of data applications

(c) Inter-System Interface (ISI) allows interconnection of TETRA networks from different manufacturers

(d) Gateways provide access between the TETRA network and other networks

(e) Network Management Interface provides a standard means to remotely monitor and configure network equipment

(f) Line Station interface permits the connection of third party dispatch systems.

(5) TETRA Voice + Data Facilities

(a) Clear or encrypted: Individual calls; Group calls; Acknowledged group calls; Broadcast calls.

(b) Circuit switched data: an end-to-end circuit at a fixed data rate. Selection of data transmission rates and error protection levels.

(c) Data Rate (kbps)

Unprotected : 7.2 , 14.4 , 21.6 , 28.8

Standard Protection : 4.8 , 9.6 , 14.4 , 19.2

High Protection : 2.4 , 4.8 , 7.2 , 9.6

(6) TETRA speech

(a) Duplex speech calls (time division duplex)

(b) Packet switched data: connection oriented or connectionless. TETRA protocols: CONP, SCLNP

(c) Short data service: optimized for the exchange of short messages

(d) Pre-defined status messages (range of over 32,000 values)

(e) User messages variable in length up to 2047 bits.

(7) The TETRA Air Interface

(a) Operates in the VHF and UHF frequency ranges: 150MHz to 900MHz

(b) RF carrier spacing: 25 kHz

(c) 4 communication channels multiplexed onto each carrier (TDMA)

(d) Modulation method: Pi/4 DQPSK

(e) Data transmission rate: 36kbps

(f) Net data throughput: 28.8kbps (7.2 kbps per channel)

(g) Voice Coding: ACELP

(h) Transmitter power classes

BS: 0.6W, 1W, 1.6W, 2.5W, 4W, 6.3W, 10W, 15W, 25W, 40W

MS: 1W, 3W, 10W, 30W

3.3 EDACS (Enhanced Digital Access Communications System)

(1) EDACS System Overview

Enhanced Digital Access Communications System (EDACS) is available in VHF, UHF, 800 and 900 frequency bands and wideband (25 kHz) and narrowband (12.5 kHz) configurations. This spectrum resource provided a springboard for the development of trunking systems. Public service radio manufactures working with Associated Public-Safety Communications Officers (APCO) developed a requirements document (APCO 16) for trunked radio systems.

EDACS provides coordinated communication between agencies and integrates all services; Dispatch, Secure Voice, Telephone and Data within a single common communication system. EDACS systems have a single control channel communicating between the system and the field radios. These configurations range from Basic EDACS to EDACS Level 4, consisting of Voted and Simulcast Systems. An EDACS Multisite Network links Systems together via a Multisite Controller (MSC) or Integrated Multisite and Console Controller (IMC).

There are two types of radio channel designations used in EDACS: One of them is the Control Channel and the other is the Working Channel. The Control Channel is used to send digital data between sites to the radios. This data is continually transmitted to the field units. The Working Channel sends voice and data over the air.

(2) EDACS Fleet mapping

Establishing a fleet map structure dictates the max number of agency and fleet calls which can be assigned. Within the fleet map structure, the more agencies that are setup, the more agency calls that can be assigned. The same is true for fleet calls. To enhance each agencies flexibility, you can have different fleet and sub-fleet structures for each agency to suit specific radio communications requirements.

A group call is addresses using a Group ID (GID). The GID is composed of 11 bits to define a total of 2048 max groups. The fleet map is structures for each agency to suit their specific requirements.

(a) Maximum of 5 bits to be used for agencies

(b) Minimum of 1 bit to be used for fleets

(c) Minimum of 2 bits to be used for sub-fleets

Some examples of the possible fleet maps are shown below (similar to Motorola Fleetmaps)

Table 3.1. EDACS Fleet Map.

Agencies	Fleets	Sub-fleets
2	32	32
2	16	64
2	8	128
2	4	256
4	32	16
8	8	32
8	16	16
16	16	8

The most common fleet map used by EDACS systems is 8 (3 bits) agencies, 16 (4 bits) fleets and 16 (4 bits) sub-fleets. If we take a couple of examples of group calls, you can easily see how simple the fleet structure really is.

Using a 3/4/4 structure, we can now partition the 11 bit Group ID (GID) as follows:

___ / ___ /____

Agency Fleet Sub-fleet

Binary examples are shown below:

Agency 1, Fleet 1, Sub-fleet 1 (GID 273 Decimal)

0 0 1 / 0 0 0 1 / 0 0 0 1

Agency 1, Fleet 1, Sub-fleet 15 (GID 287 Decimal)

0 0 1 / 0 0 0 1 / 1 1 1 1

A group call for Agency 1, Fleet 1, Sub-fleet 0 (GID 272) is a Fleet group call. All sub-fleets in Agency 1, Fleet 1 will respond to the call. A binary representation is as follows:

0 0 1 / 0 0 0 1 / 0 0 0 0

When an EDACS radio sees the fleet call assignment (GID 272), it immediately associates Sub-fleet 0 as being a Fleet call for Agency 1, Fleet 1. If the radio's channel selector is on a sub-fleet within Agency 1, Fleet 1, the radio hears the call.

A group call for Agency 1, Fleet 0, Sub-fleet 0 (GID 256) represents an Agency Group call. All fleets and sub-fleets in Agency 1 will respond to the call. A binary representation is as follows:

0 0 1 / 0 0 0 0 / 0 0 0 0

When the radio sees the Fleet call assignment (GID 256), it will immediately associate Fleet 0, Sub-fleet 0 as being an Agency call for Agency 1. If the radio's channel know is on a sub-fleet within Agency 1, the radio will automatically hear the call on GID 256.

This type of fleet mapping ensures Agency Fleet calls under failure mode of operation (such if the Site Controller were to fail).

IV. ACTIONET NETWORK ARCHITECTURE

4.1 ACTIONET Network Structure

A MX mobile exchange of a local network can switch up to 192 channels serving a maximum of 6,000 subscribers. A larger system network can be formed with an SX system exchange as in Figure 16. It is able to serve up to 50,000 subscribers. The actual maximum subscriber's capacity in any particular case, however, depends on traffic characteristics and the availability of lines and channels.

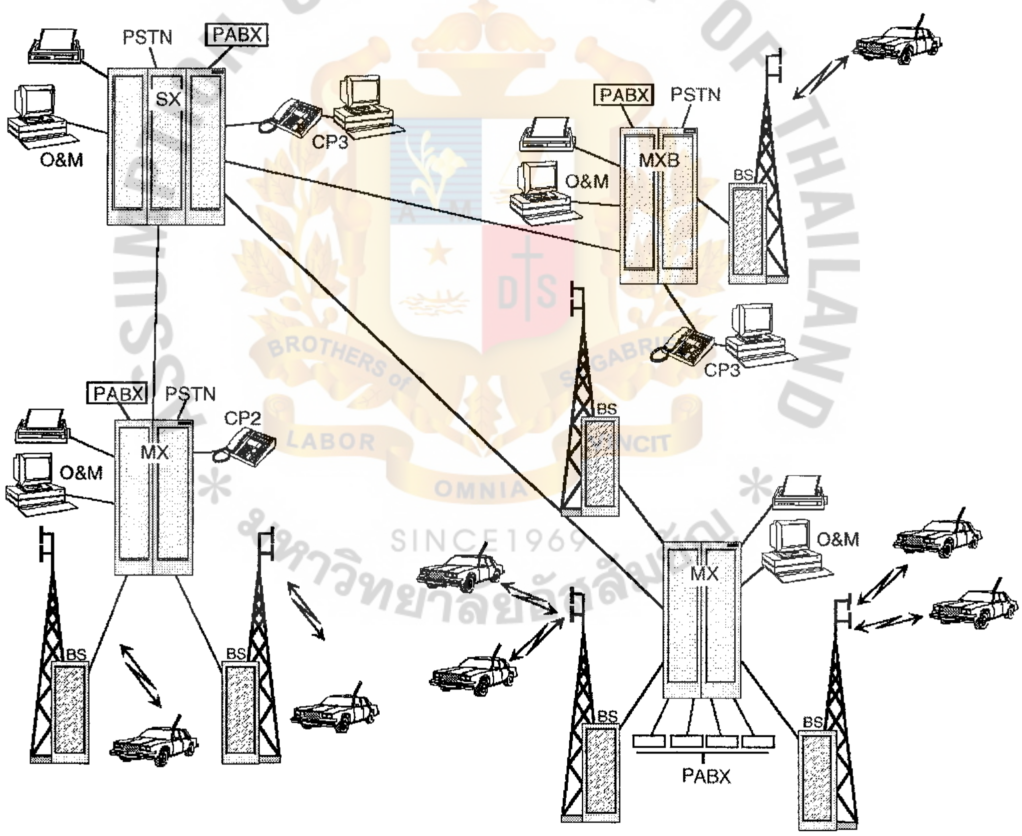


Figure 4.1. A Typical ACTIONET Network.

When an even larger or geographically distributed radio system is needed then several networks can be connected to form an extended network or an integrated network. An extended network consists of MXs, and SXs, and can serve up to 20,000 subscribers. In an extended network, automatic routing of call is managed by the Roaming Information Handler (RIH) which maintains a subscribers location database. Separate system networks can also be linked to each other. The System Roaming Handler (SRH) interconnects separate system networks (SXs) to an integrated network. It is able to handle as many as 120,000 subscribers.

4.2 Network Topology

ACTIONET provides a variety of networking topologies to enable networks. Starting from a single site system with less than 100 users up to a nationwide system with up to 120,000 users. A topology is selected depending upon the extent of the network, functional and reliability requirements, traffic patterns, etc.

ACTIONET network topologies are:

(1) Local network

(2) System network

(3) Extended network

(4) Integrated network

ACTIONET system can be built gradually. Each exchange can be upgraded to larger capacities, existing base station can be upgraded with more channels and network types can be changed from smaller networks to higher capacity networks. The investment costs can be thus divided over several phases and the initial investments can be kept low. For example, a network operator could start from local exchange and a small amount of channels and expand with more channels until the need for an additional exchange emerges.

Local Network

Local network is the smallest ACTIONET network. A local network is used for small, geographically limited systems. It consists of one mobile exchange, MXB or MX, and a number of base stations.

The MXB is an exchange version that is designed for integration into a base station site. However, there can be several base stations connected to the MXB, one of which resides in the same premises as the exchange. A MXB network is suitable for single site operation and in a system network where lines between MXB exchanges and base stations must be optimized to reduce line costs. The call control computers of the MXB are not duplicated as in the MX exchanges and therefore, it is recommended only for networks that do not need to provide absolute security. A MXB unlink the MX can not be upgraded to larger sizes than 32 ports.

An example of an MXB network is shown in Figure 4.2.

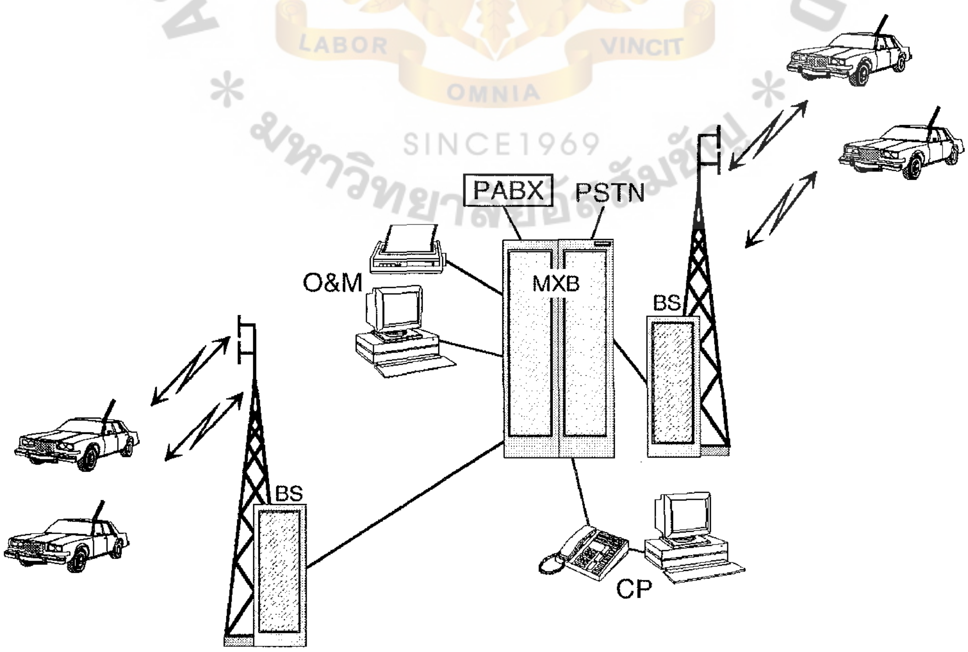


Figure 4.2. Local MXB Network.

A local network centered on a MX (Figure 4.3) is suitable configuration when several base stations are connected to the exchange and, added reliability is required.

A typical application of a local ACTIONET network is a system:

(1) with 2…60 radio channels

(2) having 1…30 radio sites

(3) serving 200…3000 radio units, depending on traffic requirements and the Number of sites and channels.

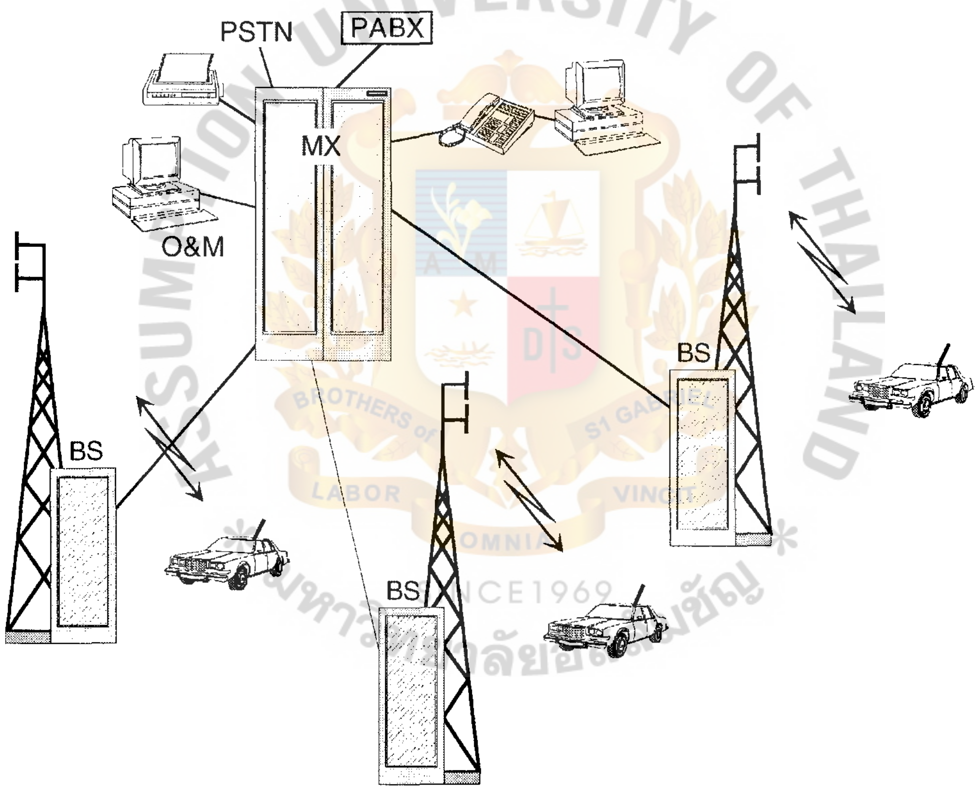


Figure 4.3. Local MX Network.

System Network

When a single MX does not provide enough subscriber capacity or the network has to be distributed to optimize line costs, a system network should be considered. A system network usually covers a uniform region or even a whole country.

A system network is typically used when:

(1) the capacity requirements exceed those satisfied by a local network

(2) the system is expected to cover a uniform area in which radio units are likely to roam regularly

(3) operational areas of the subscribers overlap with MX exchange areas

(4) the same facilities are required within the whole area.

The fixed part of the network is composed of base stations, mobile exchanges (MXB or MX) and a SX system exchange. The SX and MXB/MX are configured as a star network, the SX serving as the central node. The base stations can be connected only to the MXs, which are linked to the SX. Up to 16 mobile exchanges can be connected to the SX. If duplicated signaling lines between the SX and MX are used, the maximum number of local exchanges is 8. An example of a system network is shown in Figure 4.4.

The system network provides the user with the same facilities as the local network. The system network enables automatic roaming of mobile radio units within the whole network area by maintaining a centralized subscriber's location database. Calls are routed automatically between the exchanges.

A System network provides the same services for the subscribers regardless of the location of the subscriber within the system network area. In a nationwide system network, a subscriber can utilize the same services no matter in which MX it is located. On the other hand, the operator/owner of the network can limit the access of the subscriber to single base station or a group of base stations (Acquisition Authorization Data). Group call coverage areas can cover sites in different MXs.

The operation and maintenance of a system network is centralized to the operation and maintenance terminals of the system exchange enabling centralized network management. For example, in the system network the main subscriber database is stored in the SX enabling centralized subscriber management and administration.

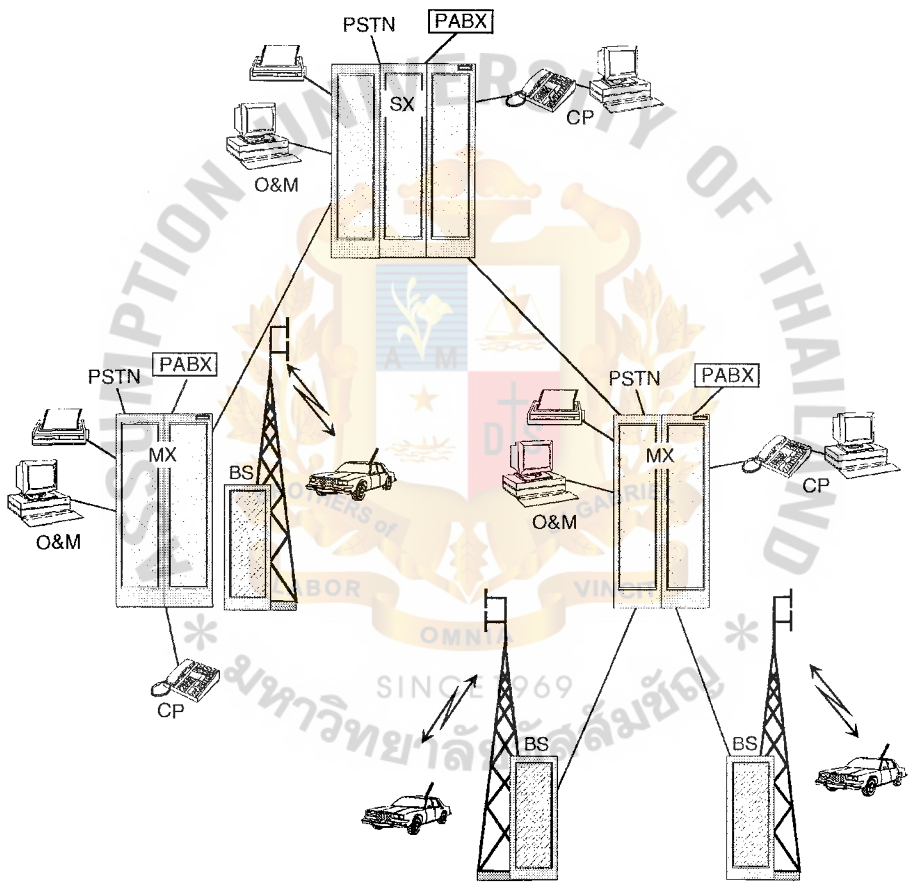


Figure 4.4. A Typical System Network.

Extended Network

ACTIONET networks, including up to 32 SXs and MXs, can be interconnected to form an extended network. In an extended network, a Roaming Information Handler

(RIH) provides automatic roaming and call routing of voice calls between individual networks.

An extended network is normally used to join together isolated network islands of local networks or system networks. A typical example of an extended ACTIONET network is a nationwide system consisting of several ACTIONET networks each serving a single region. The network for any region may be either a local or a system network, depending on the size of the region and the traffic requirements.

An extended network is particularly useful when:

(1) the total area is large and consists of relatively independent areas

(2) radio units tend to stay within own network rather than roam freely

(3) communication is mainly concentrated within an area, but there is significant demand for calls between areas as well.

Call facilities between networks in an extended network include individual voice and modem calls. Status and short data messages can be transmitted through the RIH between SX exchanges and independent MX exchanges. Extended data messages are confined within the individual networks. The call access rights of roaming subscribers should be defined separately in each sub-network of an extended network.

The RIH contains the central subscriber location database of an extended network. Whenever a radio unit enters a network, the network sends a registration message to the RIH via an X.25 network. The RIH then sends a registration deletion message to the network in which the radio unit was earlier registered.

An example of a typical extended network is shown in Figure 4.5.

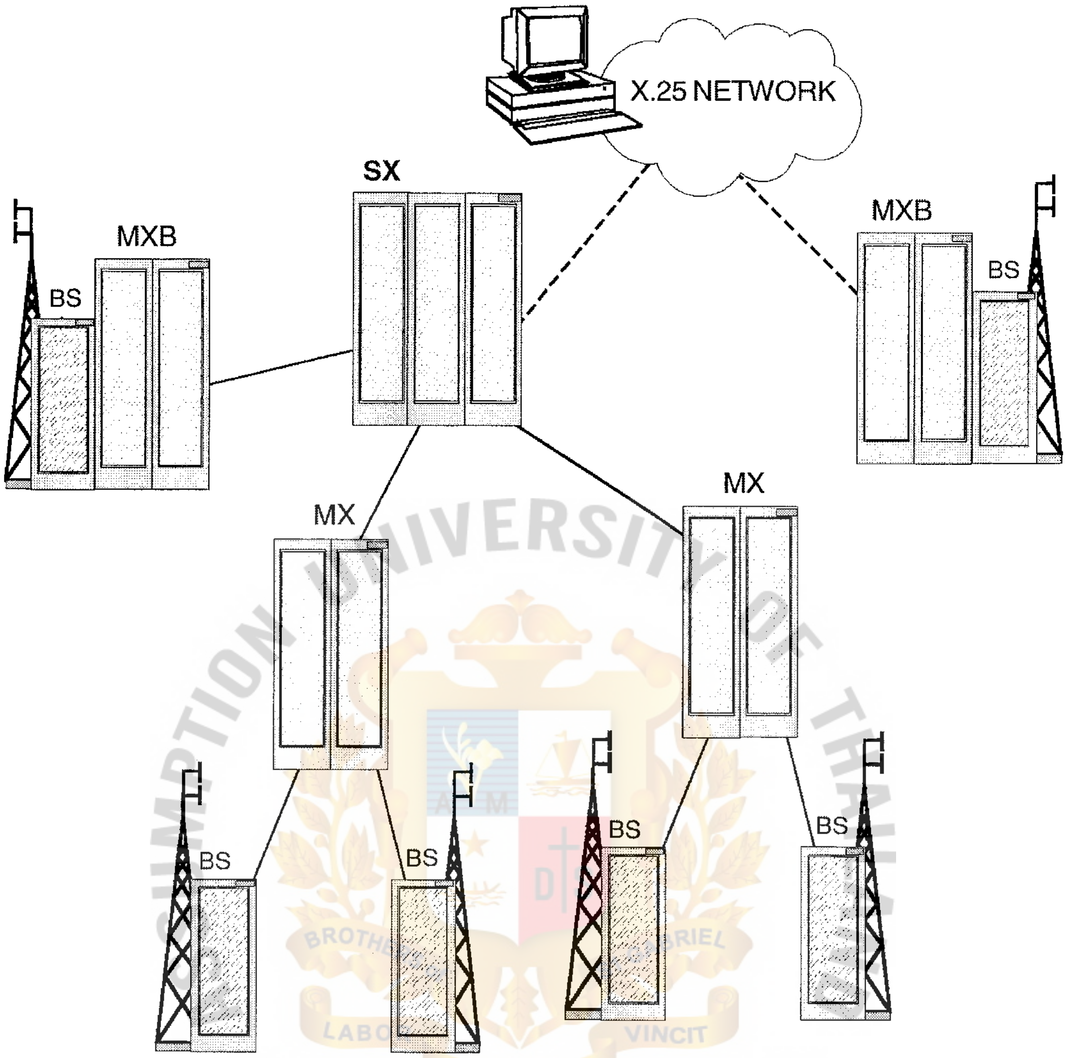


Figure 4.5. Extended Network

Integrated Network

An integrated network joins up to 16 system networks together enabling a wide range of call facilities within the entire integrated network. For instance, separate system networks of the same operator can be linked together. The integrated network allows for more extensive call traffic and roaming than an extended network.

Subscribers that roam between networks are defined in only one system network and their call access valid throughout the integrated network. In regular use, the roaming subscribers do not even recognize the change of the system network.

An integrated network solution is useful when:

(1) large subscriber capacity is required

(2) the total area is large and consists of several system networks

(3) radio units roam between system networks

(4) extensive data communication and call traffic between system networks is needed.

A system Roaming Handler (SRH) enables automatic roaming of radio units between interconnected system networks. The SRH consists of a subscriber location database and a Home Network Directory (HND) of subscribers. When a subscriber roams from an ACTIONET network to another, its definitions are retrieved from its home network. The SRH is linked to the system exchanges through an X.25 mode.

In addition to individual voice and modem calls, an integrated network is capable of handling the following call facilities between the interconnected system networks:

(1) status messages

(2) short data messages

(3) extended data messages

(4) PABX calls

(5) call diversions.

If there are no fleet specifications of the subscriber in the current network, PABX extension of the home network and emergency calls are routed according to the common definition in the current network.

An example of an integrated network is shown in Figure 4.6.

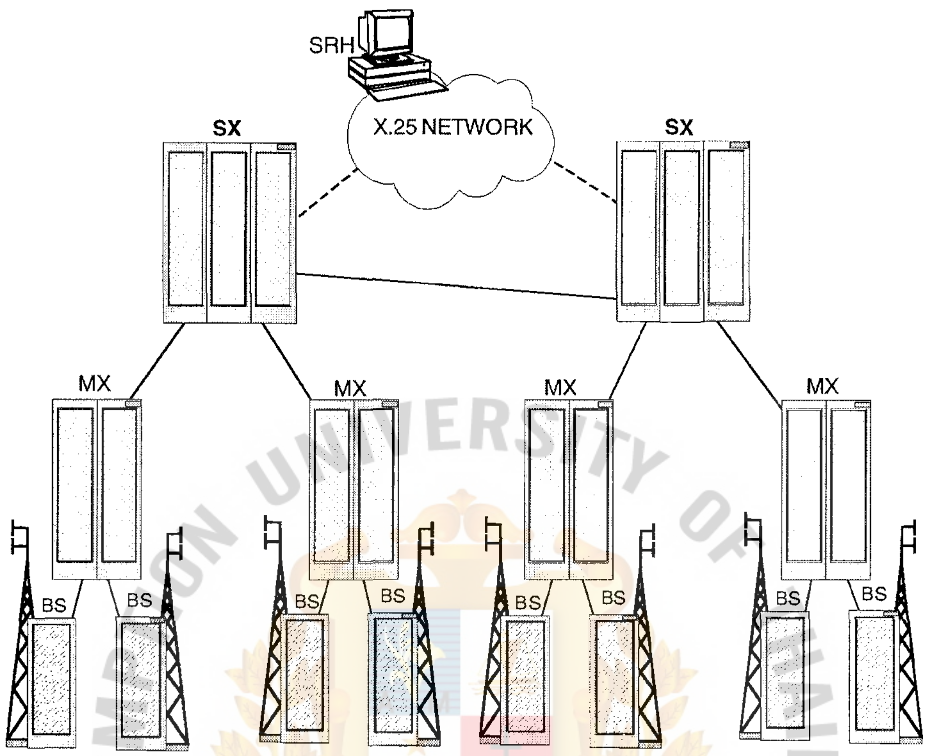


Figure 4.6. Integrated Network.

4.3 Channel Concept

(1) Radio Channels

Communication between the infrastructure and the radio units is transmitted on radio channels (pairs of frequencies, one for transmitting and one for receiving). A radio channel used for signaling is called a control channel. The channels used for user communications, either speech or modem data are called traffic channels.

Each base station site typically operates a single control channel and a number of traffic channels. In data intensive applications and large networks, multiple control channels in one site (up to 4) can be used. For instance, mobile radio units can be dedicated to different control channels in one base station site so that speech communication is handled by a different control channel.

Radio channels can be re-used either at a safe distance (cellular concept) or on nearby sites if dynamic channel allocation is used.

(2) Control Channel Strategies

(a) Control Channel Functions

A control channel is a radio channel reserved for signaling between the network and the radio units for the purpose of:

(1) call setup

(2) registration of radio units

(3) status and data message transfer

A control channel also identifies the system, as well as the base station site, providing a kind of beacon for radio units searching for an appropriate base station to use.

In the event of control channel failure, one of the remaining traffic channels automatically takes over as control channel.

(b) Dedicated Control Channel

When a system has a sufficiently large number of channels and subscribers, it is convenient, as well as efficient, to assign a dedicated channel at each base station site to act as the control channel. This type of control channel is called a dedicated control channel.

The method is relatively simple from the point of view of network planning, and provides reliable and fast access to the system in the event of an emergency. On the other hand, the channel capacity is not efficiently used if the local traffic density is low.

(c) Non-Dedicated Control Channel

In certain applications, when base station circuit costs are significant or the number of channels is limited, non-dedicated control channels may be applied. It provides efficient use of available channels and lines in low call traffic areas.

When all the traffic channels are in use, the control channel can also be used as a traffic channel. While the control channel is in traffic channel use, signalings as call set-up are not possible. The first free traffic channel becomes the new control channel.

(d) Time-Shared Control Channel

When traffic density is low, the allocated channels can be utilized more efficiently by using time-shared control channels. This means that several base station sites share a single radio channel, which is sequentially used for control. The channel is, however, still dedicated in the sense that it will not be allocated for traffic use. An example of a time-shared control channel is shown in Figure 4.7.

A time-shared control channel has a slightly more limited capacity and longer calls setup times than a dedicated control channel. Connections of emergency and high priority calls can still be ensured. To make sure of proper operation on time-shared control channels, the radio units shall be able to use enhanced Nokia specific time-shared control channel signaling.

(e) Mixed Control Channel Strategies

Dedicated, non-dedicated and time-shared control channels can be mixed in the same network. It is even possible to use the same channel as a dedicated control channel in one area and as a time-shared control channel in another area.

A reconfiguration of the network from the O&M terminal is possible, should it become necessary to change the control channel arrangements within the network.

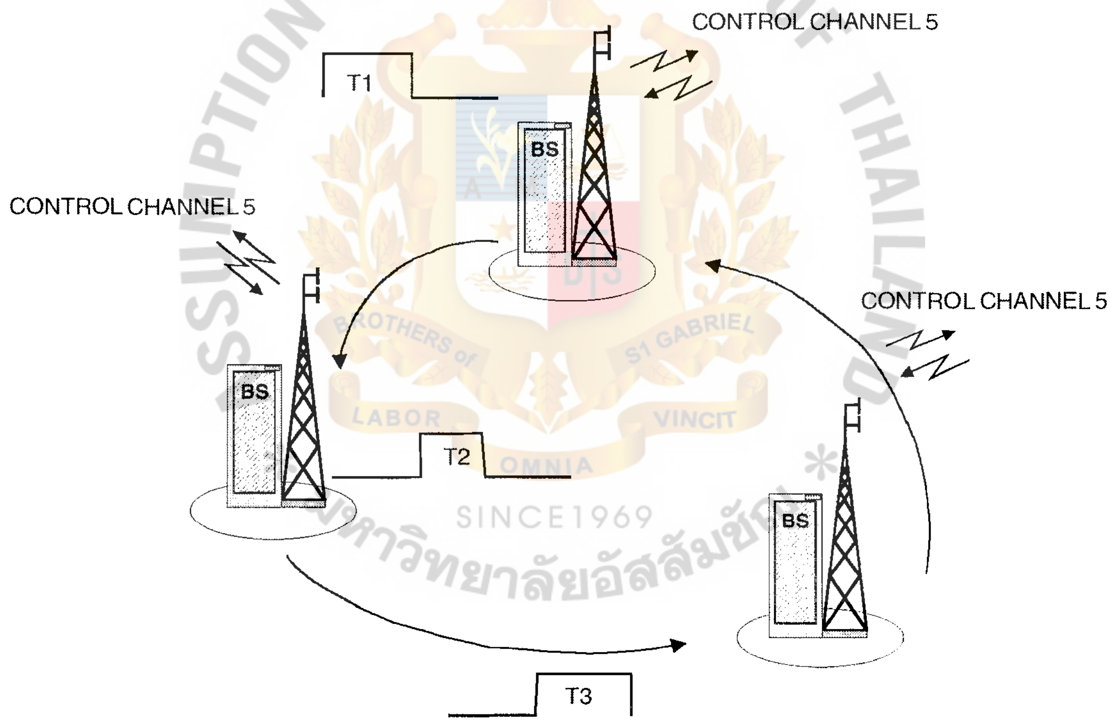


Figure 4.7. Time-shared Control Channel.

(3) Roaming and Registration

(a) General

In an ACTIONET network, radio units may roam freely within the network. Each unit can be called in the same manner, regardless of the location of the unit, as long as the unit resides within the coverage area of the system. This feature, also encountered in public cellular telephone networks, is called roaming.

Registration is simply the action whereby the radio unit declares its location to the system after the control channel search and site selection procedure.

The operation area of individual subscribers can be defined by using Acquisition Authorization Data (AAD). It determines in which registration areas of the network a subscriber is allowed to operate.

(b) Control Channel Search and Site Selection

A radio unit performs a control channel search in hierarchical levels as described in MPT 1343. The radio unit has at least two criteria to judge the quality of the signal from a base station; the actual radio frequency (RF) signal strength and the bit error rate (BER) of the received signaling. The limit values of these criteria are defined separately to select a new control channel and to leave the present one. A new channel is selected mainly on the basis of the signal strength. The BER is used mainly to determine when to leave the current control channel. The evaluation of the BER requires additional time and thus the method is not very effective when a new control channel has to be found quickly.

Alternatively, an ACTIONET radio unit can change the control channel to a new control channel with better signal, even if the BER criteria does not require the radio unit to leave the present control channel. The ACTIONET method ensures a fast and efficient site switching when the subscriber is moving, and it is recommended when time-shared control channels are used.

Regardless of whether the site change is initiated by a full control channel search or the relative monitoring of the signals from different sites, the new site is always confirmed as described in MPT 1343.

(4) Allocation of Traffic Channels

(a) Call Setup

To economize on the use of radio channels Full Off-Air Call Setup (FOACSU) is normally used, which means that the traffic channels are not allocated for the call unit the called party has answered. In the case of calls to the PSTN (Public Switched Telephone Network) this is not usually applied because the called subscriber may mistake the possible queuing tone for the engaged tone and hang up.

(b) Normal Procedure

The system allocates a free traffic channel for a call at the site, which the radio unit has selected, i.e.

(1) for the calling party: the site via which it has transmitted the call request.

(2) for the called party: the site via which it sends the acknowledgement when it is being searched for.

If the calling and called parties select the same site, only one traffic channel on that site is normally used for the call. However, where duplex mobiles are concerned, both parties is either allocated their own traffic channel or mobile radio units are directed to semi-duplex mode on the same traffic channel. This is dependent on the choice of system parameters and call type.

(c) Dynamic Channel Allocation

Dynamic allocation of traffic channels is, like time-sharing of the control channel, a technique for increasing the effective use of radio frequencies in areas where the traffic density is low, coverage problems exist or traffic moves from one area to another depending on the time of the day. Typically, there are fewer channels available than base station sites (e.g. 4 channels and 5 base station sites). Very often time-shared control channel is used with dynamic traffic channel allocation as in Figure 4.8.

The mobile exchange allocates channel frequencies to base station sites according to call requests. Allocation is done so that the same frequencies are not used simultaneously on nearby sites, which could interfere with each other.

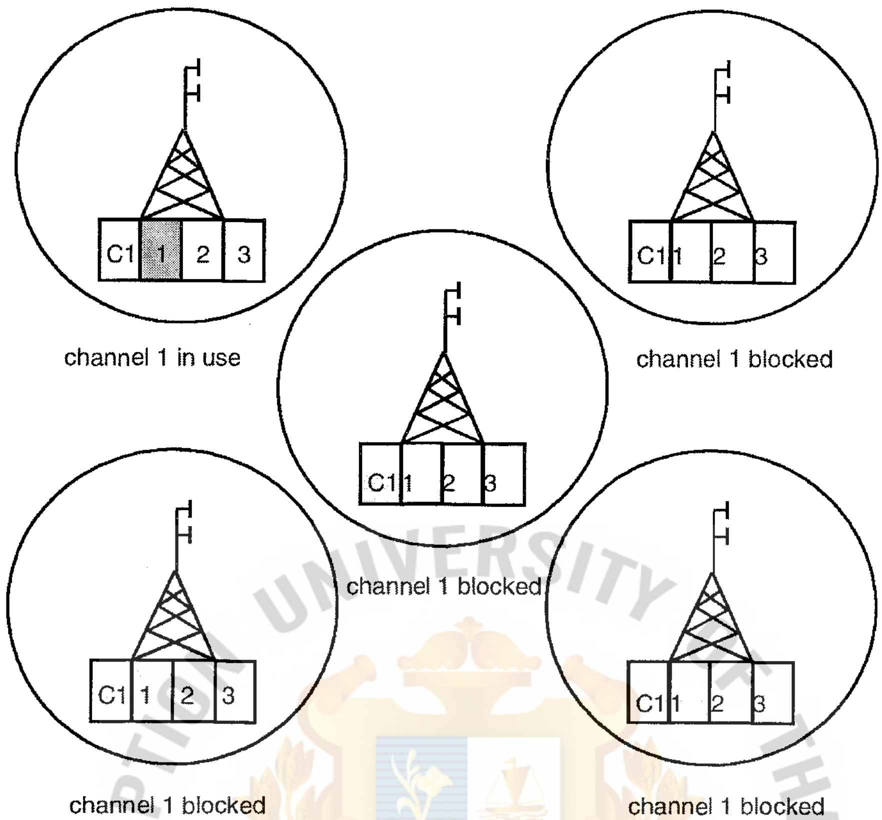


Figure 4.8. Dynamic Traffic Channel Allocation and Time-shared Control Channel.

V. SIGNALLING SEQUENCES IN ACTIONET NETWORK

5.1 General Operational Sequences

(1) Registration

After switching on the radio unit or when not reaching the minimum signal field strength on the control channel it searches for a suitable control channel. In addition to checking the field strength of the received signal the radio also checks various signaling parameters, such as TSC identification (SysID), and compares these with its programmed values. After having found a suitable control channel, the radio has to register on this channel.

TSC ----> Radio units

……	ALH(2)	ALH(0)	ACK	ALH(2)	...

Radio units --> TSC

……		RQR			

Figure 5.1. Registration.

ALH(2) synchronisation message of the TSC

RQR registration request of the mobile unit

The TSC may send the following answers to the registration request:

(a) ACK - accept it.

(b) ACKX - reject it.

(c) ACKI - hold and decide later.

Only after a successful registration the radio unit is allowed to stay on this control channel.

(2) Roaming

After not reaching the minimum value of signal field strength for a certain time period the radio starts to search for a new control channel (roaming). The radio contains a list of possible frequencies or a certain allowed frequency range. If it finds any other channel of proper field strength and with an authorized SysID the radio starts the registration procedure according to (1).

(3) Call Set-up

Once a radio unit has sent a call request (RQS), the TSC will inform the radio unit about the current state of the call set-up. This is done by forwarding acknowledgements (ACK-messages).

Call is rejected:

(a) ACKI (Q=O) called party occupied.

(b) ACKV (Q=0) called party not ready.

(c) ACKX (Q=0) invalid call.

(d) ACKX (Q=1) no traffic channel available.

Call was received/is queued:

(a) ACKQ (Q=0) call queued, wait till traffic channel is available.

(b) ACKI (a =0) call set-up in progress, wait for further information

An ALH-telegram is sent to the radio unit of the called party by the TSC which has to be answered with an ACK (availability check). The TSC subsequently assigns a speech channel to the radio unit using the GTC-

(5) Call Monitoring

An existing communication between two or more radio units on one speech channel is monitored by the TSC. For this purpose maintenance and clear-down telegrams are sent:

(a) MAINT (OPER= 000) PTT pressed.

(b) MAINT (OPER= 001) PTT released.

(c) MAINT (OPER= 010) periodic call according to time criteria.

(d) MAINT (OPER= 011) subscriber ends call (call clear down).

The TSC can determine which telegrams have to be sent using Broadcast (BCAST)-messages (SYSDEF = 00010). The TSC is able to disconnect certain radio units or prohibit them from transmitting (MAINT), clear the call (CLEAR), allocate a different traffic channel (GTC); check whether certain radio units are still on the traffic channel (AHY).

(a) MAINT - (110) Call clear down for all, only one or a group of radio units.

(b) MAINT - (111) transmission prohibited.

(c) CLEAR terminates the call for all radio units and sends them back to the control channel.

(d) GTC transfers all subscribers to a different speech channel (TC replacement).

(e) AHY requests a certain subscriber unit to send an acknowledgement (ACK), to check his availability.

Certain time criteria are monitored both in the TSC and in the radio unit. In order to avoid blocking of the PTT-key the radio units have a transmission time limited. There are certain timers running during a call.

After elapse of the timer without a proper action the TSC clears the call:

(a) TN - activity on traffic channel (squelch).

(b) TP - maximum time between periodical telegrams (MAINT-(O10)).

(c) TT - maximum conversation time.

(6) Call Clear-down

A call can be cleared for certain or all radio units because of one or more of the following reasons:

(a) Clear-down request of radio unit (MAINT(011)).

(b) Exceeding of one or more time criteria as described in (4).

(c) No more maintenance calls received.

When the call is terminated by the TSC all radio units switch to the indicated control channel. In all other cases the radio units return to the previous control channel. If they can't find this channel any more they start the roaming procedure. As an option it is possible to indicate to the radio unit the elapse of the maximum conversation time a few seconds before that by sending a short tone.

(7) Call Back Memory

Many radio units provide a call back memory function. If the radio unit leaves his mobile unattended incoming calls are stored. The unit displays a message, that there are calls stored. After returning the user can scroll the list of received calls and recall the other party.

The system supports all necessary signaling procedures for this function.

(8) Call Time Limits

Different limits for the duration of each type of communication can be entered on the OMC. The range goes from as short as 10 seconds up to as long as 18 hours. Any conversation exceeding this limit will be cleared down by the system. In order to inform the user, an audible tone can be generated a few seconds before exceeding the limit.

5.2 Calling Procedures

For call set-up distinction is made between calls to:

(1) Radio units of the same network i.e. prefix (common prefix).

(2) "Visitors", i.e. radio units of another network, who have registered in this network (interprefix).

(3) Line-unit subscribers, who can be directly accessed (PABX, PSTN, and line dispatcher).

(4) Subscribers, who can only be accessed via a system addresses (idents greater 8100).

Calls to subscribers of a) and c) can easily be set up with a RQS-message (individual call). Call set-up to subscribers of d) is similar to interprefix calls (b)). Each subscriber has his own subscriber number (own ident). In addition to that, he may belong to various user groups, so he may have more than one group ident. Signaling and call set-up are similar for simple calls and group calls, except that the availability check is omitted for group calls.

(1) Radio Unit Calls Radio Unit With Same Prefix

The simple call has three steps:

(a) Call request.

(b) Availability checks.

(c) Channel allocation.

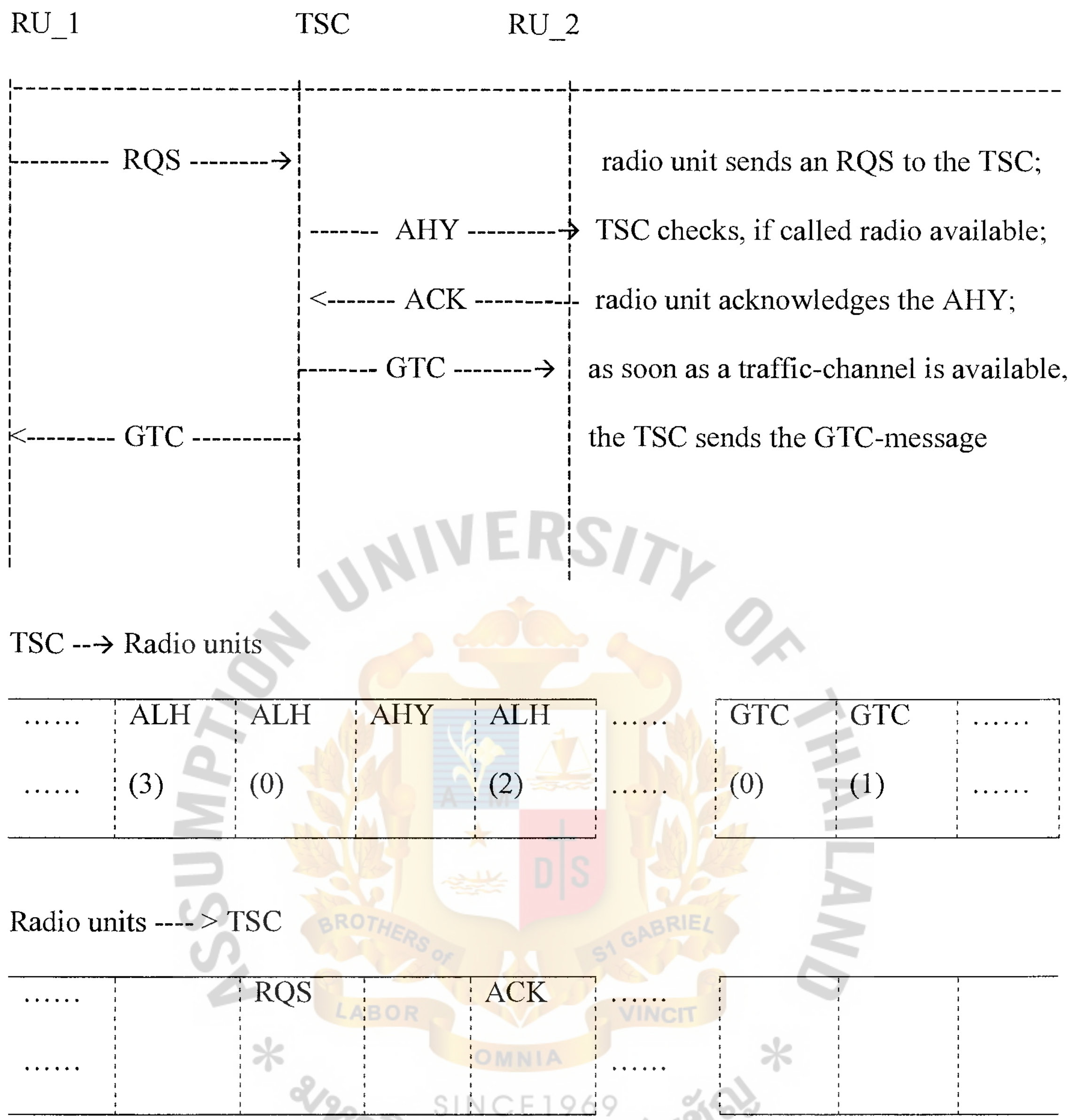


Figure 5.2. Radio Unit Calls Radio Unit with Same Prefix.

(2) Radio Unit Calls a Group call

This sequence consists of two signaling phases:

(a) Call request.

(b) Traffic channel allocation.

(For group calls, the availability of the subscribers to be called is not checked) In this example, all traffic channels are in use when the call request is received so that the request is queued.

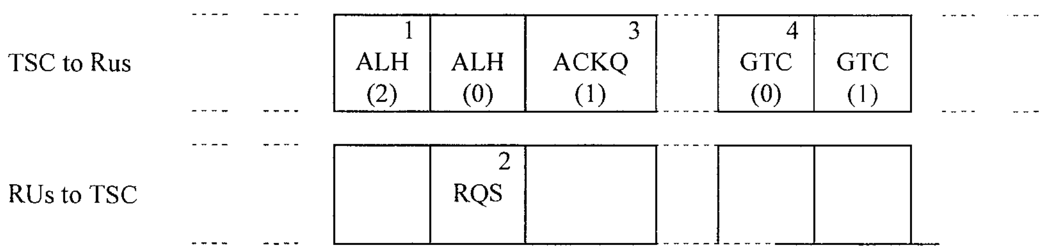


Figure 5.3. Radio Unit Calls a Group Call.

ALH General invitation to RU to transmit call requests.

Frame length is two time slot (N = 2)

RQS Call request from RU1

ACKQ TSC acknowledges call request and informs RU1 that the call has been queued until a channel is available.

GTC When a traffic channel is available, a common channel is allocated both to the called group and to the calling RU (GO TO CHANNEL message). In this example, the GTC message is repeated for added reliability.

Alternative acknowledgements from the TSC are available if, for instance, the call request is invalid or the system is overloaded. If a traffic channel is available when a group call is requested then the TSC may omit the ACKQ and send the GTC command immediately. In this example, the

GTC message is repeated immediately. However, repeat messages may be delayed for other signaling.

(3) Data Transmission (Control or Traffic Channel)

Data messages of different types can be sent on the control or on the traffic channel.

(a) Control Channel

For not exceeding traffic load on the control channel, only two types of messages are permitted:

Status messages (RQQ-telegram)

Status-messages can be transmitted to the TSC, to a radio unit or a line dispatcher.

Within the RQQ-telegram a 5-bit message field is defined. This gives the possibility to send up to 32 different status-messages. The definition of the meaning of each message is determined in the radio unit with the exception of the following two messages:

00000 - Call back request

11111 - Cancel call back request

This means that 30 user definable status messages are available. The TSC acknowledges a RQQ-message within ACKQ-telegram.

Short Data Message, Extended Data Message (RQC, HEAD-Telegram)

Short data messages can be sent to all subscribers connected to the network excluding PSTN and PABX. The message field may accommodate up to 184 bits which can be sent in up to 4 data messages. 184 bits are equal to 23 ASCII-characters or 46 BCDfigures. The subscriber initializes a short data message with a RQC-request. Data are transmitted using the HEAD-message followed by up to four data messages(Extended Data Message). Figure 5.4 is a message sequence on a control channel for sending a short data message from one radio unit to another radio unit. In this example, the data message comprises of an address codeword and two appended data codeword; (each of the data codeword contains 46 bits of free format data). In the sequence, the radio unit sends its request; the TSC instructs the to send the data message, forwards the data message to the called unit and then indicates the success of the transaction to the calling unit.

TSC To RUs	1 ALH (3)	ALH (0)	3 AHYQ	ALH (0)	ALH (2)	5 HEAD	5 data	ALH (2)	7 ACK (1)	ACK (1)
RUs To TSC		2 RQC		4 HEAD	4 data			6 ACK		

Figure 5.4. Short Data Message.

ALH General Aloha invitation.

RQC Random access request to transmit a shot data message. . (The request indicates the number of timeslots required for the data message : in this case, two slots.)

AHYQ Short data invitation message

- acknowledges the RQC message
- instruct the calling unit to send the data message in the next two slots.

HEAD + data The calling radio unit sends its short data message to the TSC. In this example the message comprises an address codewoed (HEAD) and two appended data codewords.

HEAD + data The TSC forwards the shot data message to the called radio unit.

ACK Acknowledgement sent to the calling unit to indicate that the called unit has accepted the data message. In this example the TSC immediately repeats the ACK message, for added reliability.

(b) Traffic Channel

Each call set-up can be requested for speech conversation or for data transfer. Data transfer requires the following amendments to speech conversation procedures:

(1) Only the maximum conversation time is monitored.

(2) No periodic MAINT-telegrams allowed.

(3) Protocol and mechanism are user defined.

VI. CONTROL CHANNEL LOAD MODEL AND PREDICTION SOFTWARE

6.1 Control Channel Load Model

Control channel load monitoring is important because control channel signaling is vital to system operation, but the signaling capacity of control channel is rather limited. In accordance with the MPT1327 specification, the standard signaling speed is only 1200 bit/s (See detail of control channel structure in appendix A). The control channel may become congested especially in system where a large part of user traffic is data messages, which are transmitted over the control channel. If control channel load is predictable, the operator can take corrective action before congestion starts to hinder system operation.

Control channel load in this study case is classified into relative load of incoming and outgoing.

The following parameters are used in the control channel load model:

(1) R slots (Number of received incoming signaling slots)

Return signaling slots that contained signaling from radio units. E.g. all requests from radio units like RQS, ACK, RQD, etc.

(2) A slots (Number of available random access slots)

Return signaling slots that were available for random access from radio units. E.g. if the system sends ALH(5) onto the downlinks to indicate a random access frame, it means that there will be 5 slots available on the uplinks. These are the A-slots.

(3) E slots (Number of outgoing empty slots)

Dummy forward signaling slots on forward signaling channel.

(4) O slots (Number of outgoing slots)

Total number of slots on the forward signaling channel.

(5) EST. RTN (Relative Incoming Load)

Relative load on the return signaling channel (from radio units to TSC) in this sample.

(6) EST. FWD (Relative Outgoing Load)

Relative load on the forward signaling channel (from TSC to radio units) in this sample.

6.2 Meaning of the Relative Load Values

The relative load values are of special interest.

Relative incoming load (EST. RTN) is calculated as follows:

$$\frac{\text{Number of received incoming signaling slots ("R-slots")}}{\text{Number of slots available for random access ("A-slots")}} * 100$$

Normally the peak value of this ratio should not exceed 50%. The average value, calculated over a period of at least 10 minutes, should be below 25%.

Relative outgoing load (EST. FWD) is calculated as follows:

$$\frac{\text{Number of outgoing signaling slots ("O-slots" – "E-slots")}}{\text{Total number of outgoing slots ("O-slots")}} * 100$$

The highest acceptable value of this ratio depends on the requirements for speed of call set-up and data message delivery. The average value should be around 50%, the peak value should remain below 80%.

6.3 Parameters Slots in Each Call Sequence

From Section V, we can categorize call sequence such as Registration, Individual call, Group call and Short Data Message call to show A-slot, R-slot, E-slot and O-slot as below.

(1) Registration

TSC ----> Radio units

……	ALH(2)	ALH(0)	ACK	……

Radio units --> TSC

……		RQR		……

Figure 6.1. Registration Sequence.

For registration sequence we found that A-slots are 2 slots because ALH(2) is on the forward signaling channel (refer to control channel load model of this section), R-slot is 1 slot (RQR), E-slot is 1 slot (ALH(0), refer to control channel load model of this section), O-slots are 3 slots.

(2) Individual Call

A –slots for individual call sequence are 5 slots. They come from a random access protocol of ALH(3) and ALH(2) on forward signaling channel (TSC → radio unit). R-slots are 2 slots (from Radio units → TSC). E slot is 1 slot (ALH(0) on TSC → Radio units) and O-slots are 6 slots.

TSC --→ Radio units

......	ALH	ALH	AHY	ALH	......	GTC	GTC	......
......	(3)	(0)		(2)	......	(0)	(1)	......

Radio units ---- > TSC

......		RQS		ACK	......			
......					......			

Figure 6.2. Individual Call Sequence.

(3) Group Call

TSC → RUs	1 ALH (2)	ALH (0)	3 ACKQ (1)	4 GTC (0)	GTC (1)
RUs → TSC		2 RQS			

Figure 6.3. Group Call Sequence.

A group call sequence has 2 of A –slots. They are ALH(2) forward signaling channel (TSC → radio unit). R-slot is 1slot(from Radio units → TSC). E slot is 1 slot (ALH(0) on TSC → Radio units) and O-slots are 5 slots.

(4) Short Data Message Call

TSC	1		3			5	5		7	
To	ALH	ALH	AHYQ	ALH	ALH	HEAD	data	ALH	ACK	ACK
Rus	(3)	(0)		(0)	(2)			(2)	(1)	(1)

Rus		2		4	4			6		
To		RQC		HEAD	data			ACK		
TSC										

Figure 6.4. Short Data Message Call Sequence.

A –slots of short data message call sequence are 7 slots. From a random access protocol, they are ALH(3) and 2 of ALH(2) on forward signaling channel (TSC → radio unit). R-slots are 4 slots (from Radio units → TSC). E slots are 2 slots (2 of ALH(0) on TSC → Radio units) and O-slots are 10 slots.

From above the information, we can summarize parameter slots of all call sequences to illustrate in a format of table as below.

Table 6.1. Parameters Slots.

Call Sequences	R slots	A slots	E slots	O slots
Registration	1	2	1	3
Individual Call	2	5	1	6
Group Call	1	2	1	5
Short Data Message Call	4	7	2	10

All of these values keep in "cal.ini" file for calculation reference.

6.4 Prediction Software

The following flowchart shows the main task of prediction software. The listing of Delphi program is found in Appendix C.

This program starts to read all parameters from "cal.ini" file. The set of parameter is initiated. Then the program illustrates the window with random values of parameter. After that, user needs to clear all data and enters new data, the program checks the completion of data in every row and column. If data is not complete, it shows an error message that use for correction, then it calculates both relative incoming and outgoing load.

Figure 6.6 is a starting window of prediction software.

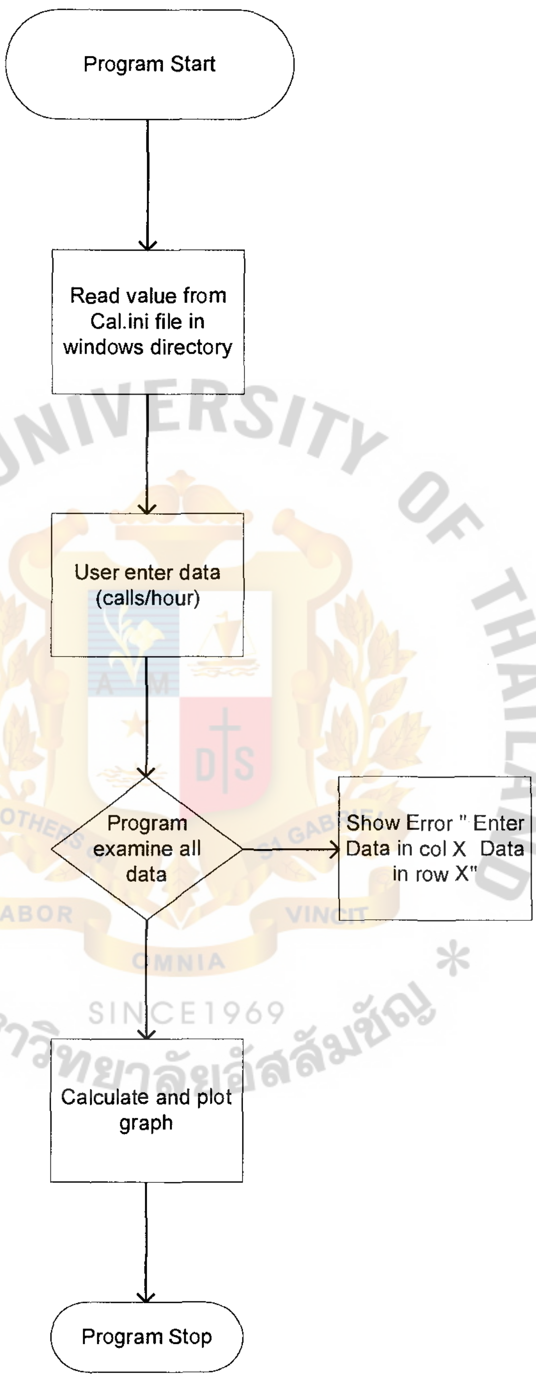


Figure 6.5. The Main Task of Prediction Software.

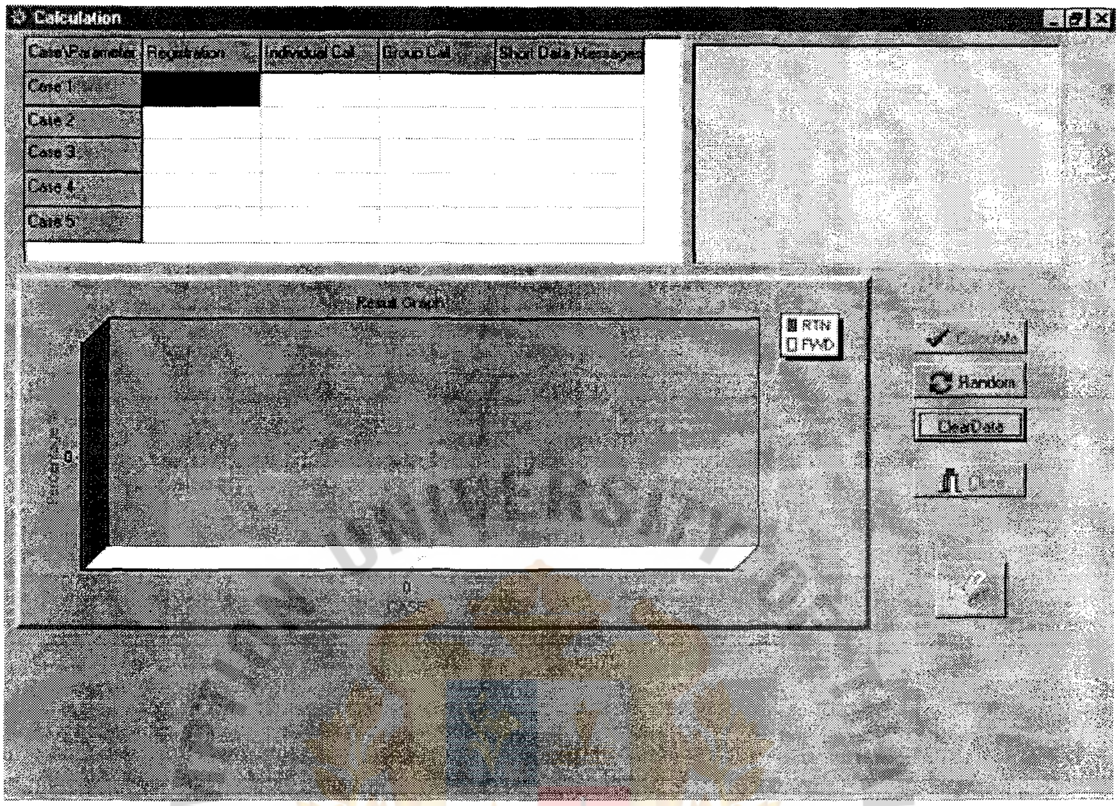


Figure 6.6. The Prediction Software's Window.

VII. THE STUDY CASES

7.1 The Effect of Short Data Message on the Control Channel Load in MPT1327 Trunked Radio Network

The effect of short data message on the control channel load in MPT1327 trunked radio network is investigated by using load parameters such as relative incoming load and relative outgoing load. The used input parameters to investigate the control channel load prediction are shown in Table 7.1.

Table 7.1. Input Parameters for Each Case.

Case / Call Sequences	1	2	3	4	5
Registration (calls/hour)	10	10	10	10	10
Individual Call (calls/hour)	10	10	10	10	10
Group Call (calls/hour)	10	10	10	10	10
Short Data Message Call (calls/hour)	4	6	8	10	12

In this study we assume that the number of call per hour of another call sequences are 10 calls per hour in each case. Only the number of call per hour of short data message call is vary.

The short data message is vary following the Table 7.1. There are 5 cases in this study.

Case 1: The short data message is 4 calls per hour. The short data message lengths are 100 characters.

Case 2: The short data message is 6 calls per hour. The short data message lengths are 150 characters.

Case 3: The short data message is 8 calls per hour. The short data message lengths are 200 characters.

Case 4: The short data message is 10 calls per hour. The short data message lengths are 250 characters.

Case 5: The short data message is 12 calls per hour. The short data message lengths are 300 characters.

The parameters used to investigate the effect of short data message on control channel load in MPT1327 trunked radio network are relative loads. The relative loads are relative incoming load and relative outgoing load. Therefore, the results of both relative loads are shown in Figure 7.1.

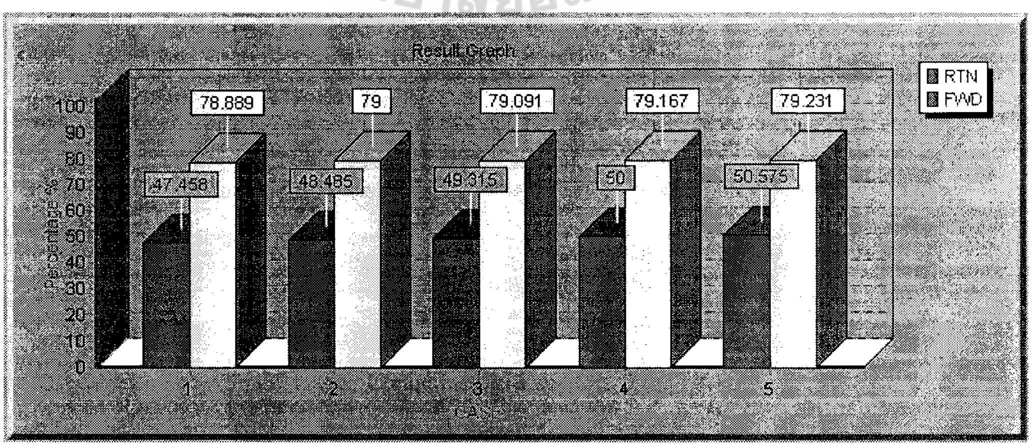


Figure 7.1. The Result Graph.

(1) Relative Incoming Load

Table 7.2. Relative Incoming Load by Case.

Case	1	2	3	4	5
Percentage	47.458	48.485	49.315	50	50.575

From the result, when the number of short data message calls per hour is increased, the relative incoming load is increased. The value of relative incoming load of case 4 (10 short message data calls per hour, 250 characters) meets the peak value limitation (not over 50%) which is explained in Section VI.

(2) Relative Outgoing Load

Table 7.3. Relative Outgoing Load by Case.

Case	1	2	3	4	5
Percentage	78.889	79	79.091	79.167	79.231

From the result, when the number of short data message calls per hour is increased, the relative outgoing load is increased. The value of relative outgoing load of case 4 (10 short message data calls per hour, 250 characters) meets the peak value limitation (remain below 80%) which is also explained in Section VI.

VIII. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

There are 5 systems of MPT1327 trunked radio network in Thailand. They are categorized into public network and private network.

The public networks are RadioPhone, WorldRadio and Public Radio Network (PRN). RadioPhone used to be a joint venture company between Jasmine International Group and Telecom Holding under concession from The Telephone Organization of Thailand (TOT). Now TOT manages RadioPhone. WorldRadio is the number one of this market share with its concession from The Communications Authority of Thailand (CAT). WorldRadio is managed by United Communication Industry PCL (UCOM). The last operator is PRN which is a joint venture company between CAT, Sahaviriya OA Group and Telecom Holding.

The private networks are Provincial Electricity Authority (PEA) and Bangkok mass Transit System PCL (BTS).

The system vendor of RadioPhone, PRN is Philips. But the system vendor of WorldRadio, PEA and BTS is NOKIA.

This study aims to create a tool for all MPT1327 trunked radio network operators, especially the public network operator who has a lot of short data message traffic.

The results from investigation into the effect of short data message on the control channel load in MPT1327 trunked radio network show that the increase of number of short data message calls per hour effect the relative incoming and outgoing load.

The relative incoming load result shows that if the number of short data message call is not over 10 calls per hour, the control channel load is not over 50%.

The relative outgoing load result shows that if the number of short data message call is not over 10 calls per hour, the control channel load is not over 80%.

Both of them do not exceed the normal peak value described in Section VI.

The conclusion of this study is that the short data message call can be used if the number of call is not over 10 calls per hour. The short data message call can not be used to transfer many messages because it increases the loading to control channel. Therefore, the signaling system dimensioning should consider the number of short data message call per hour when the network provides this application.

8.2 Recommendtions

The popularity of using the MPT1327 trunked radio comes from the ease of use that likes conventional radio but the signal strength is better and the coverage area is wider than conventional radio. In Europe, MPT1327 trunked radio has a roaming service. The radio can be used in the country that has a roaming agreement.

The advantages of MPT1327 trunked radio are, the radio channel can be shared among many user groups, several user organizations and data message service. That can make one step ahead when compared to conventional radio.

The main users of WorldRadio are in these businesses: insurance, transportation, construction and industrial estate. These customers need to talk from one person to many persons in the same time such as a supervisor commands his/her subordinators to work. This is an advantage of trunked radio.

Nowadays, WorldRadio proposes an Automatic Vehicle Location System (AVLS) to a transportation company. This application helps the management staff to monitor and control the limited resource. AVLS use a short data message call on WorldRadio network and we use this prediction software to monitor the loading on control channel.

In term of cost saving, UCOM has been investing 200,000 Baht for one person who studies this topic. On the other hand, if UCOM purchases this feature software. We have to pay one and a half million Baht. Then, we can reduce a huge cost.

For further study, I recommend a software development to predict site by site loading. The conceptual of software is to collect call detail records and distinguish to what site we want to predict.

APPENDIX A

SIGNALING STRUCTURES

SIGNALING STRUCTURES

A. Basic Control Channel Structure

The signaling structure on the control channel is shown in Figure A.1. After the start-up sequence, the TSC divides the control channel into time slots. Exactly one message can be transmitted in each time slot. Signaling on the forward control channel (TSC - > RU) is continuous. Each time slot of the forward control channel comprises of two 64-bit codewords:

(1) A Control Channel System Codeword (CCSC)

(2) An Address Codeword

Exceptions may arise when longer messages are transmitted by the TSC, i.e. when data codewords are appended to an address codeword. In this case, both the CCSC and the address codeword will be displaced as illustrated in Figure A.2. The TSC may not displace the CCSC by more than two successive time slots because of inserted data codewords.

A radio unit receives a message from the TSC in one time slot, sends a reply in the next time slot of the return control channel and immediately switches back to the forward control channel to be able to receive a message from the TSC.

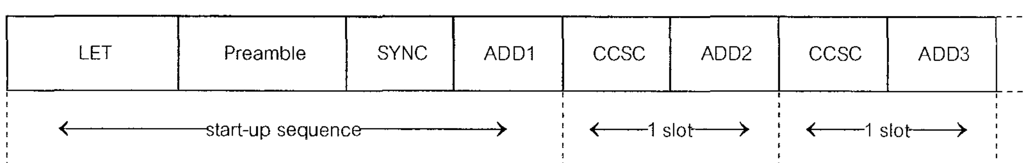
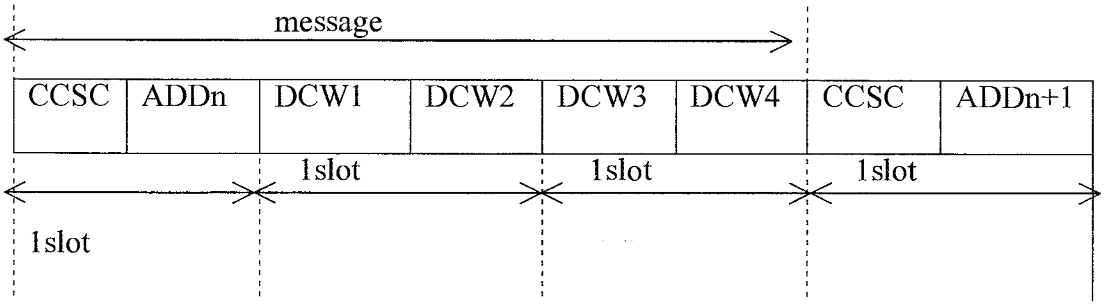


Figure A.1. Basic Control Channel Format.

Start-up sequence	Sent by a base station just commencing transmission on the control channel.
LET	Link Establishment Time Signaling transmission is preceded by a link establishment time. During this time the output power reaches 90% of the maximum power. The LET is at least 6 bits long (5ms).
Preamble	1010 … 10 sequence used for synchronizing the receiver at the beginning of signaling. The preamble is at least 16 bits long and always ends with logic 0.
SYNC	Control channel codeword synchronization sequence This synchronization sequence is at least 16 bits long (SYNC = 1100010011010111).
Message	A message consists of a codeword synchronization sequence, an address codeword and, where appropriate, one or more data codewords (see Figure 35).
ADDn	Address codeword
CCSC	Control Channel System Codeword



CCSC	Control Channel System Codeword.
ADDn	Address codeword .
DCWm	Data codeword in message.

Figure A.2. Example of Data Codeword Displacement.

B. Control Channel Signaling Messages

The message sent on a control channel may be classified as follows:

Aloha messages	Sent by the TSC to invite and control random access.
Requests	Sent by radio units to request calls/transactions.
AHOY messages	Sent by the TSC to demand a response from an addressed radio unit.
Acknowledgements	Sent by the TSC and by radio units.
Go To Channel messages	Sent by the TSC to allocate traffic channels.
Single address messages	Currently sent only by radio units.
Short data messages	Sent by the TSC and by radio units.
Miscellaneous messages	Sent by the TSC for system control.

C. Codeword Structures

Messages are transmitted in the form of 64-bit codewords. Each codeword contains 48 information bits and 16 check bits. As already mentioned, there are two types of codeword (address and data codewords), which are distinguished by the first bit to be transmitted (see Figure A.3).

Bit no.	1	2 48	49 64
	A	Information field	Check bits
No. of bits	1	47	16

Bit 1(A)	Bit 1 = 1 Address codeword
	Bit 1 = 0 Data codeword
Bit 2 to 48	Information field
Bit 49 to 64	Check bits

Figure A.3. Codeword Structure.

In the following, the CCSC (Control Channel System Codeword) as a special data codeword and the general address codeword structure are described.

(1) Control Channel System Codeword Structure (CCSC)

The control channel system codeword is transmitted on the control channel by the TSC. It identifies the system to the radio unit, i.e. the radio unit recognizes from the codeword whether it is programmed for the particular system. The codeword is also used for time slot synchronization. The CCSC is a data codeword, structured as shown below.

	0	SYS	CCS	PREAMBLE 1010101010101010	P 1100010011010111
No. of bits	1	15	16	16	16

Figure A.4. Control Channel System Codeword Structure (CCSC) (TSC->RU)

0 Data codeword

SYS System Identity Code

Identification code of operating system

CCS Codeword Completion Sequence

This bit sequence is chosen that the parity check bit sequence (P) always forms the control channel codeword synchronization sequence (SYNC = 1100010011010111). The CCS sequence is related to the SYS sequence via an algorithm, The SYS sequence must be chosen that the CCS sequence produced does not correspond to the SYNC sequence.

Preamble 1010 … 10 sequence for receiver synchronization.

It contains at least 16bits and ends with a logic0.

P Parity check bits

These bits terminate the codeword and always form the control channel codeword synchronization sequence (SYNC).

(2) Address Codeword Structure (ADD)

This codeword defines the type of message. There is a general address codeword structure which is divided into 8 categories, plus one special for the GTC (Go To Channel) message. The general and GTC structures are distinguished by bit22 of the codeword; bit22 of the general structure is always '1' whereas bit22 of the GTC codeword is set to '0'.

Figure A.5 shows the general address codeword structure.

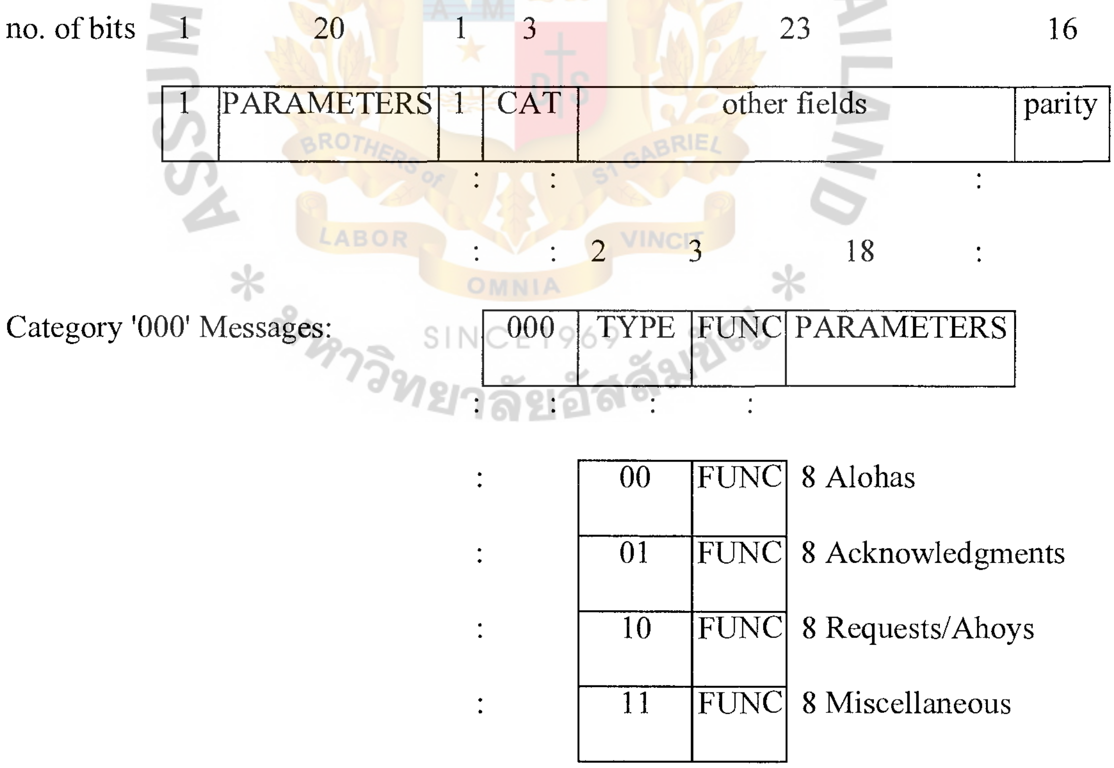


Figure A.5. The Most Usual General Structure of Address Codeword.

: : 2 22

Category '001' Messages:

001	TYPE	PARAMETERS

: : :

: 0	Single address messages
: 1	Short Data Message

: : :

Category '010' Messages:

010	KIND	PARAMETERS

: : :

: 0	Standard Data GTT and DGUG messages
: 1	Standard Data RQD and AHYD messages

: : :

011	spare
100	spare

: :

Category '101' Standard Data Messages:

101	KIND	JOB	PARAMETERS

: : :

011	Reserved
100	Reserved

Figure A.5. The Most Usual General Structure of Address Codeword. (Continued)

Categories zero and one (CAT = '000' and '001') contain standardized codewords. The "reserved" codewords are intended for future expansion of the standard message set, whereas the "spare" codewords may be used for customization of services.

It is anticipated that reserved categories could be used for the definition of polling and data communication protocols etc. in a future phase of standardization.

(3) List of Address Codewords

		Mnemonic	Meaning
GTC Message:		GTC	Go to channel command
CAT '000' Messages:			
	TYPE '00'	Aloha invitations:	
		ALH	general
		ALHS	standard data excluded
		ALHD	"Simple" calls excluded
		ALHE	emergency only
		ALHR	registration or emergency
		ALHX	registration excluded
		ALHF	fall-back mode
		reserved	
	TYPE '01'	Acknowledgements:	
		ACK	general
		ACKI	intermediate
		ACKQ	call queued
		ACKX	message rejected
		ACKV	called unit unavailable
		ACKE	emergency
		ACKT	try on given address
		ACKB	call-back / negative ack
	TYPE '10	Requests (sent by RUs):	
		RQS	"Simple"
		RQD	standard data
		RQX	cancel/abort
		RQT	divert
		RQE	emergency
		RQR	registration
		RQQ	status
		RQC	short data
		Ahoys (sent by TSC):	
		AHY	general availability check
		spare for customization	

	AHYX	cancel alert/waiting state
	reserved	
	reserved	
	reserved	
	AHYQ	status message
	AHYC	short data invitation
TYPE '11'	Miscellaneous:	
	MARK	control channel marker
	MAINT	call maintenance
	CLEAR	call clear-down
	MOVE	move control channel
	BCAST	broadcast
	reserved	
	reserved	
	reserved	

CAT '001' Messages:

TYPE '0'		Single address messages:
	SAMO	Outbound
		Inbound:
	SAMIU	inbound unsolicited
	SAMIS	inbound solicited
TYPE '1'	HEAD	Short data message

CAT '010' Messages: Codewords applicable to Standard Data

Kind '1'	RQD	Request for Standard Data
	AHYD	Availability check
Kind '0'	GTT	Go To Transaction
	DRUGI	Radio Unit General Information

CAT '011' Messages: spare

CAT '100' Messages: spare

CAT '101' Messages: Standard Data

KIND '0'

JOB	FROM TSC	FROM radio unit
'0000	DACK+DAL	
'0001'	DACK+DALG	
'0010'	DACK+DALN	
'0011'	DACK+GO	DACK+GO
'0100'	DACKZ	DACKZ
'0101'	DACKD	DACKD

'1000'	DAHY	RSVD
'1001'	RSVD	RSVD
'1010'	RSVD	DRQG
'1011'	RSVD	RSVD
'1100'	DAHYZ	DRQZ
'1101'	RSVD	RSVD
'1110'	DAHYX	DRQX
'1111'	RLA	RLA

KIND '1'

TASK

'0'	SACK	SACK
'1'	SITH	SITH

CAT '110' Messages: reserved

CAT '111' Messages: reserved

(4) Go To Channel Message, GTC

This message is transmitted on a control channel from a TSC to radio units. It directs the addressed radio units to switch to a designated channel and proceed with communication.

This message may also be transmitted on a traffic channel to move radio units already in communication to a replacement traffic channel. When the units have retuned to the replacement channel, communication may continue.

	1	PFIX	IDENT1	0	D	CHAN	IDENT2	(N)	P
No. of bits	1	7	13	1	1	10	13	2	16

Figure A.6. Go To Channel Message Structure.

PFIX Unit or group prefix.

IDENT1 Called party or gateway:

Ident for a common-prefix call, a call from a PABX extension or from the PSTN, or an Include calls.

Ident for an interprefix call when the message is sent to the called party.

IPFIXI for an interprefix call when the message is sent to the calling party.

ALLI for a system-wide call.

PABXI for a call to a PABX extension.

PSTNSIj for a call to a prearranged PSTN destination.

PSTNGI for a call to a general PSTN destination.

DUMMYI or TSCI for an inter-site call where the calling party is active on the same control channel.

D '0' if the addressed radio units shall unmute the audio (for speech communication).

'1' if the addressed radio units shall mute the audio (for data communication), and need not send maintenance messages within items unless required by the system by pre-arrangement.

CHAN Designates the allocated channels number.

IDENT2 calling party or gateway:

	Ident	for a common-prefix call to a unit or group of units, a system-wide call, or a call to a PABX extension or to the PSTN.
	Ident	for an interprefix call when the message is sent to the calling party.
	IPFIXI	for an interprefix call when the message is sent to the called party.
	PABXI	for a call from a PABX extension.
	PSTNGI	for a call from the PSTN.
	INCI	for an Include call.
	DUMMYI or TSCI	for an inter-site call where the called party is active on the same control channel.
(N)	Aloha number. See random access protocol (APPENDIX B).	
P	Parity check bits.	

APPENDIX B

RANDOM ACCESS PROTOCOL

RANDOM ACCESS PROTOCOL

A control channel is provided for handling all control functions of the radio units that can be accessed by signaling. The control channel is a half-duplex channel.

For the duration of the call, the mobile station leaves the control channel and changes to an allocated traffic channel (also half-duplex operation).

The stability, flexibility and efficient channel utilization of the MPT1327 standards is not only achieved through the kind of signaling protocol used (random access protocol), but also through an efficient use of the control channel.

There are two different strategies of using the control channel:

(1) Dedicated

(2) Non-dedicated

A dedicated system has a control channel permanently available for signaling. The use of a dedicated control channel is particularly appropriate for trunked systems with many channels

The use of a non-dedicated control channel is more appropriate for systems with only a few channels. In a non-dedicated system, the control channel is not permanently available. It is chosen from the total number of channels available, i.e. if all the other channels are occupied, it may also be used as traffic channel for speech and data communication.

The control channel is divided into time slot of 107 ms duration each (128 bits with a transfer rate of 1200 bits/s) (see Figure B.1).

Figure B.1 shows the basic principle of the random access protocol specified in the MPT1327 signaling standards. The random access protocol is based on a method developed by Philips, called Dynamic Frame length Slotted Aloha (DFSA). It is the heart of trunked system signaling.

Each of these time slots may contain a message to and from the trunking system controller (TSC). The TSC transmits a synchronization message (illustrated by the ALOHA message ALH (N) in Figure B.1) to the radio unit. The ALOHA message is a general invitation to the radio unit to send call request messages. The parameter (N) specifies the number of consecutive time slots (frame length) in which a radio unit can send its call requests (RQS).

If N=1, i.e. the frame length is one time slot, the radio unit may send its call request in the next time slot. If the frame consists of more than one time slot, the radio unit will choose a random slot from the frame for its message. In Figure B.1, for instance, the radio unit may send its call request in one of the 4 marked time slots.

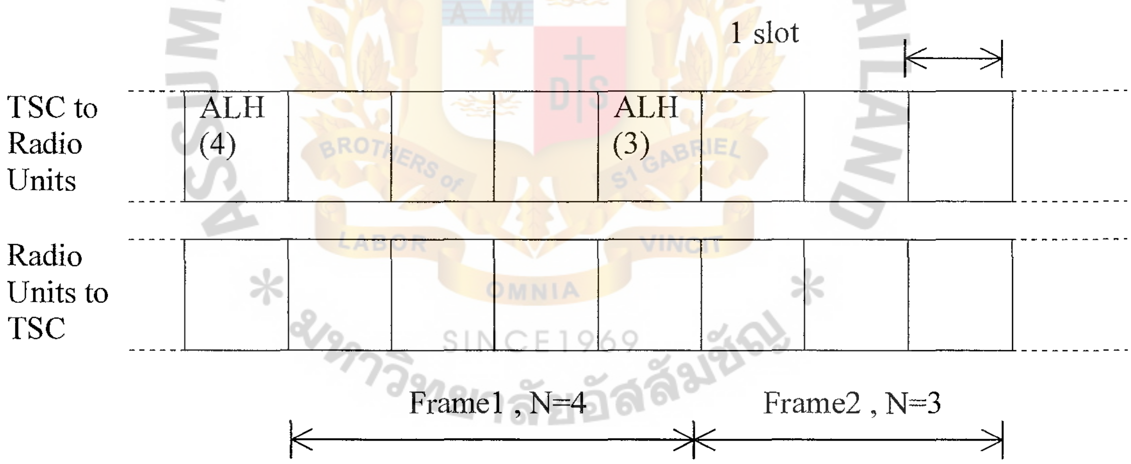


Figure B.1. Control Channel Signaling.

Two random access frames, each marked by an ALH message.

The main features of the random access protocol access protocol are:

(a) Monitoring of the activities on the control channel by the Trunking System Controller (TSC) and

(b) Optimization of the system performance by varying the frame length. This ensures:

(1) Minimum channel access delays,

(2) Peak throughput under heavy traffic load and

(3) Coordination in case simultaneous call requests from different subscribers.

(c) Full system stability under any operating conditions.

Figure B.2 illustrates the dynamic control of the frame length in the case of simultaneous call request from two or several radio units (RQS1/RQS2).

TSC to Radio Units	ALH (1)	ALH (1)	ALH (2)	ALH (0)	ACK (1)	ACK (1)
Radio Units to TSC		RQS1 RQS2		RQS1	RQS2	

Figure B.2. Dynamic Control of Frame Length.

RQS1: Request RU1
RQS2: Request RU2

(1) During periods without clashing of two or several call requests, the frame length can be one slot.

(2) If the TSC detects the clashing of several requests (RQS1/RQS2) from different radio units, it extends the frame length by increasing the ALOHA number in the next message (ALH (2)).

(3) The call requests are not acknowledged and the radio units 1 and 2 repeat their requests in different time slots (made possible by the extended frame length).

(4) Both radio units are successful. Each call request is acknowledged in the following time slot by ACKQ (1).

(5) If both radio units would accidentally have chosen the same time slot again or if a call request from a further radio unit would be clashing with one of the two call requests. The TSC algorithm would determine a new ALOHA number (i.e. the frame length is increased once more) and the process would be repeated.

(6) ALH (0) does not mark a frame, but signifies that the frame is not yet completed with the following time slot.

(7) ACKQ (1) acknowledges a request and marks a new frame. Random access frames can be defined by ALOHA, ACKNOWLEDGEMENT and GO TO CHANNEL (GTC) messages.

(8) If the TSC detects that call requests of several radio units are no longer clashing in a time slot, the frame length is reduced again to one time slot.

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