# Personal air communications technology – pACT

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**Advances in technology have allowed paging markets to evolve in recent years from simple one-way paging to more sophisticated services, such as two-way paging and mobile data. Eager to put these advances into practice, AT&T Wireless Services, Ericsson, PCSI, DATUM Telegraphic and others have joined forces to develop pACT, a new open standard for two-way paging and messaging services. pACT has its roots in cellular digital packet data.**

**The pACT protocol was developed mainly to enable compact, inexpensive devices with a long battery life to access reasonably low-cost, high-capacity network infrastructures. This two-way protocol enhances one-way paging, response paging, two-way paging, voice paging, telemetry and two-way messaging applications.**

**The author describes the pACT system, whose efficient use of valuable frequency spectrum and cellular-based structure ensure that its coverage is able to grow and adapt to operators' business needs.**

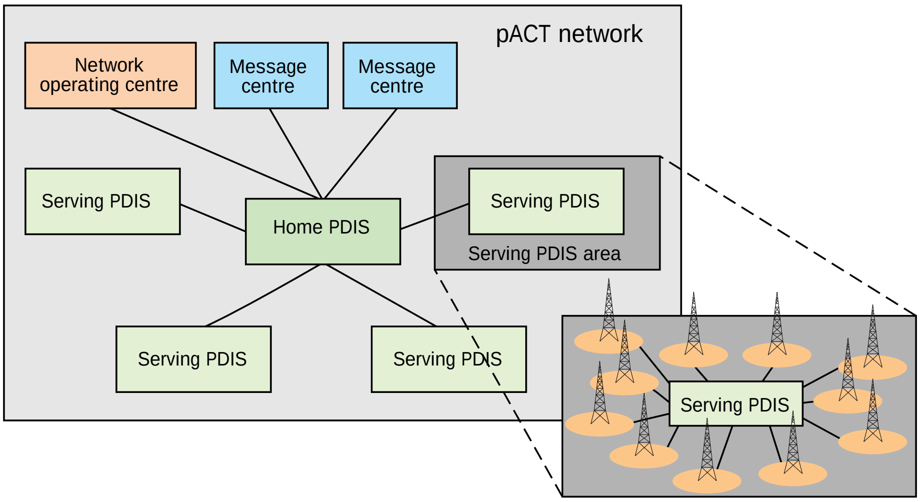



**Figure 1**
**The PDIS forms the core of a pACT network. The home PDIS serves several serving PDIS which, by means of several radio base stations, provide radio communication to a given geographical area.**

## Narrowband PCS

In 1994, the Federal Communications Commission (FCC) set aside frequency spectrum for narrowband personal communications services (narrowband PCS, or NPCS) in the USA. The narrowband PCS spectrum, which consists of a 2 MHz outbound frequency spectrum and a 1 MHz inbound frequency spectrum, Figure 2, was then divided into 34 channels and allocated to five regions, 51 major trading areas (MTA), and 493 basic trading areas (BTA):

– 11 nationwide channels
– 6 regional channels
– 11 MTA channels
– 6 BTA channels

The FCC then held auctions for regional and national coverage, granting licences to 13 companies, most of whom were well-established US paging operators. All told, the operators paid more than USD 1 billion for rights to operate in the narrowband PCS spectrum, see Tables 1 and 2. When broken down, this amount roughly corresponds to USD 2-4 per person per MHz. Further auctions for the MTA and BTA channels will be held in 1997.

In Canada, too, authorities allocated (no auctions) the narrowband PCS spectrum within the same frequency band to various companies, including Cantel, LanSer Communications and Bell Mobility.

A great deal of money has been invested in the relatively narrow radio channels. The paging industry has seen substantial

### Box A Abbreviations

| | |
|---|---|
| API | Application program interface |
| ATM | Automatic teller machine |
| BHCR | Busy hour call rate |
| BST | Base station transceiver |
| BT | Both-way trunk |
| BTA | Business trading area |
| CDPD | Cellular digital packet data |
| CMIP | Common management information protocol |
| DRAM | Dynamic random access memory |
| ERMES | Enchanced radio messaging system |
| ERP | Effective radiated power |
| FCC | Federal Communications Commission |
| FPGA | Field programmable gate array |
| FTAM | File transfer, access and management |
| GMSK | Gaussian minimum shift keying |
| GPS | Global positioning system |
| GUI | Graphical user interface |
| HPA | High-power amplifier |
| IP | Internet protocol |
| IVR | Interactive voice response |
| LAPD | Link access procedure on the D-channel |
| LSM | Limited size messaging |
| MC | Message centre |
| MDLP | Mobile data link layer protocol |
| MIB | Management information base |
| MTA | Major trading area |
| NMS | Network management system |
| NPCS | Narrowband PCS |
| OSI | Open systems interconnection |
| pACT | Personal air communications technology |
| PCS | Personal communications services |
| PDA | Personal digital assistant |
| PDB | pACT data board |
| PDBS | pACT data base station |
| PDIS | pACT data intermediate system |
| POCSAG | Post Office Code Standardization Advisory Group |
| PSTN | Public switched telephone network |
| RF | Radio frequency |
| RRM | Radio resource management |
| SMS | Short message services |
| SMTP | Simple mail transfer protocol |
| SNMP | Simple network management protocol |
| SQL | Structured query language |
| TAP | Telocator alphanumeric protocol |
| TNM | Telecommunications network management |
| TNPP | Telocator network paging protocol |
| TRX | Transceiver |
| TSM | Time slot multiplexing |
| UDP | User datagram protocol |
| WWW | World Wide Web |

growth in recent years (27% annual increase in the US between 1990 and 1995), and analysts expect this sector to continue to grow for several years to come. Nonetheless, some paging carriers are already running short of bandwidth, a dilemma that has them actively examining ways in which to add capacity to their networks. In dense markets, such as major US cities, the solution has been to make better use of existing spectrum, which is where narrowband PCS and personal air communications technology (pACT) play an important role.

The pACT protocol was originally created to address the demands of a growing market for narrowband PCS. The first pACT specification was released in October 1995. A second release, pACT97, followed in January 1997.

## pACT services and applications – "one-way paging"

Narrowband PCS is primarily seen as a means of meeting paging operators' urgent need for increased capacity. As such, a "two-way" infrastructure is deployed mainly to support a "one-way" application.

In traditional one-way paging networks, such as POCSAG (Post Office Code Standardization Advisory Group), ERMES (enhanced radio messaging service, Box B), and FLEX (Box C), messages are delivered via simulcast distribution from several transmitters with very high output power – up to several hundred watts effective radiated power (ERP). Simulcast transmissions make paging networks very efficient in terms of low operational costs and of providing good coverage from a reasonably inexpensive infrastructure. However, because they do not make efficient use of bandwidth, simulcast transmissions fall short of meeting the huge demand for paging services. This is particularly true because one-way networks have no way of knowing where a subscriber is located at any given time. Thus, to ensure that messages reach a subscriber, network operators must transmit each message over every transmitter in the network. In the US, for example, approximately 7% of some 42 million paging customers (1996) subscribe to nationwide services. Sending a message to one such subscriber via a traditional one-way paging network requires the use of as many as 2000 transmitters. Obviously, this is a waste of expensive bandwidth.

The capacity of one-way paging systems varies in accordance with the busy hour call rate (BHCR), the average message length, and the customer service profile. Local or regional subscribers, for instance, do not require the same overall level of bandwidth as nationwide subscribers. However, in zones – that is, in markets with continuous coverage – many simulcast-oriented one-way systems have already reached a ceiling on capacity. In these zones, the only way to increase capacity is to add more frequency spectrum. Adding more transmitters improves coverage, but does not affect capacity. Unfortunately, in many countries and markets around the world, more frequency spectrum simply is not available for paging or for other wireless services.

Nationwide paging systems that encompass many zones support more users than local or regional systems. Likewise, the nationwide services require much more capacity than regional or local services. A nationwide numeric service often requires as much as 25-50 times more capacity than local single-market services. Alphanumeric services, which accomodate larger messages and character sets, require still another 5-10 times as much capacity. Thus, nation-

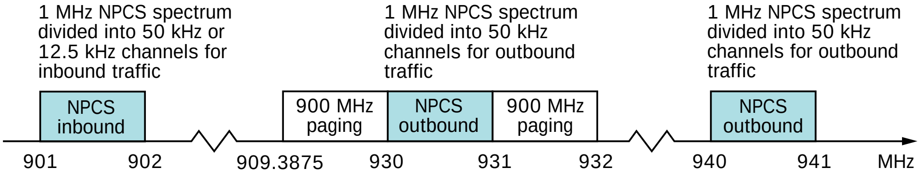
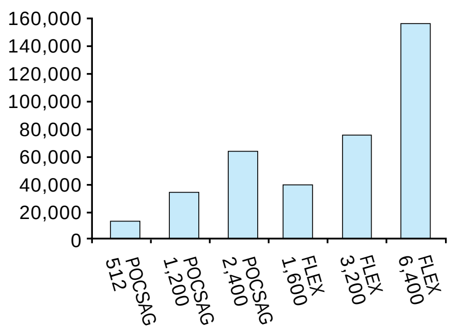



**Figure 2**
**The outbound portion of the 2 MHz frequency spectrum is divided into two blocks. One block, at 940-941 MHz, provides symmetrical 50 / 50 kHz paired channels with the 1 MHz inbound block at 901-902 MHz (39 MHz fixed duplex space). The other outbound block is located at 930-931 MHz, where its asymmetrical licences reside (50 / 12.5 kHz).**

### Box B
### ERMES

The enhanced radio messaging system (ERMES), which is a 6250 bit / s one-way paging system, was designed to be for public paging what GSM is for mobile telephony. A further enhancement of the ERMES standard, which will allow for a simple form of two-way operation, is currently being specified.

**Figure 3**
**Capacity, in number of subscribers, per system / market / zone of one-way paging protocols (based on an average 40-character message size, 25 kHz channel, call rate 0.25).**




### Box C
### The FLEX family of paging protocols

FLEX, ReFLEX and InFLEXion are paging protocols from Motorola.
FLEX is a protocol for one-way paging infrastructures. The siblings ReFLEX and InFLEXion are based on a two-way paging infrastructure. Unlike pACT, however, in order to locate subscriber devices in the network, the ReFLEX and InFLEXion protocols require a separate receiver (inbound messaging) network – normally with a very low transmission speed (800 bit / s).

The FLEX family of protocols is capable of supporting inbound transmission speeds of up to 9600 bit / s. However, to do so, while providing the same grade of service and maintaining the same geographical area that is covered by an 800 bit / s implementation, requires that many more receivers be deployed.
FLEX, ReFLEX, and InFLEXion are trademarks of Motorola Inc.

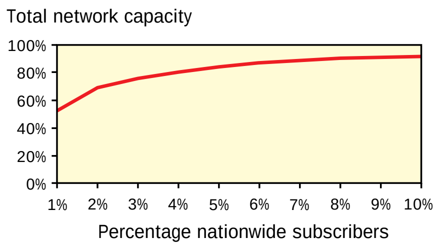
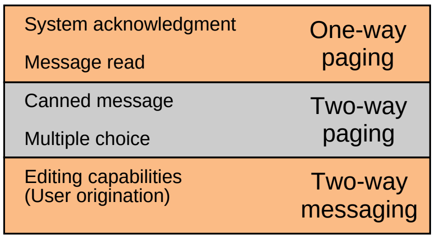



**Figure 4**
**Channel capacity required to support a 1-10% nationwide subscriber base in a 100-zone one-way paging system. All remaining users are assumed to be local (single-zone) subscribers.**

**Figure 5**
**Five levels of acknowledgement.**




wide alphanumeric services generally require 125-500 times more capacity than local numeric services. However, the operators of such services can typically only charge 5-10 times more than local numeric operators charge. Thus, although the demand for nationwide and alphanumeric services is high and growing, paging operators of simulcast-oriented one-way systems are reluctant to provide them, knowing that they can yield a greater return from investments in local numeric services.

Narrowband PCS and two-way protocols, such as pACT, give the paging industry new tools for increasing the capacity of one-way paging systems, and introduce possibilities for providing new or enhanced services. Like traditional mobile telephony systems, pACT increases capacity by reusing frequencies (providing theoretically unlimited capacity). Given higher airlink speeds (8000 bit/s) and knowing a subscriber's exact location, operators can increase capacity in a large zone 100-200 times, and even more in networks that are made up of several zones.

To the end-user, one-way paging over a two-way network offers no real benefits; however, to operators the benefits are tremendous:

- Two-way networks enable paging devices to acknowledge that a message has been received. With this capability, operators can offer their customers "guaranteed delivery". However, because most subscribers assume they already have this service, operators may find it difficult to charge them more for it. In time, guaranteed delivery may become a fundamental service.
- To reach an intended recipient, operators do not have to send a message via every transmitter in the network. Instead, because they know the exact location of each subscriber device (subscriber devices register automatically as they move about in the network) messages are sent solely via the transmitter that is closest to the subscriber, freeing up a great deal of network capacity. Thus, all other transmitters in the network can be used simultaneously to serve other subscribers.

Table 1
Summary of nationwide narrowband PCS licences

| Licences | Company | Winning bid, USD |
|---|---|---|
| 50/12.5 kHz paired | AirTouch Paging | 47,001,001 |
| 50/50 kHz paired | AT&T Wireless Services | 80,000,000 |
| 50/50 kHz paired | AT&T Wireless Services | 80,000,000 |
| 50/12.5 kHz paired | BellSouth Wireless (MobileComm) | 47,505,673 |
| 50/50 kHz paired | Mobile Telecommunications Technologies | 80,000,000 |
| 50/12.5 kHz paired | Mobile Telecommunications Technologies | 47,500,000 |
| 50 kHz unpaired | Mobile Telecommunications Technologies (Pioneer's preference licence) | 33,300,000 |
| 50 kHz unpaired | PageMart Inc. | 38,000,000 |
| 50/50 kHz paired | Paging Network (PageNet) | 80,000,000 |
| 50/50 kHz paired | Paging Network (PageNet) | 80,000,000 |
| 50 kHz unpaired | Paging Network (PageNet) | 37,000,000 |
| | | 650,306,674 |

Table 2
Summary of regional narrowband PCS licences

| Regions | Licence | Company | Winning bid, USD |
|---|---|---|---|
| 3 | 50/12.5 kHz paired | AirTouch Paging | 31,218,001 |
| 5 | 50/12.5 kHz paired | American Paging | 53,621,666 |
| 1 | 50/12.5 kHz paired | Ameritech | 9,500,000 |
| 1 | 50/12.5 kHz paired | Benbow PCS Ventures* | 35,681,000 |
| 2 | 50/12.5 kHz paired | Insta-Check Systems* | 8,000,013 |
| 3 | 50/12.5 kHz paired | Lisa-Gaye Shearing* | 52,940,007 |
| 5 | 50/12.5 kHz paired | MobileMedia | 53,669,092 |
| 5 | 50/50 kHz paired | PageMart Inc. | 92,599,020 |
| 5 | 50/50 kHz paired | PCS Development Corp.* | 151,544,001 |
| | | *40% bidding credit | 488,772,800 |

## pACT-related services and applications – other services

The two-way pACT architecture affects more than capacity: it also enables providers to enhance services, as well as to provide completely new services and applications. For example, paging devices that contain a transmitter are able to transmit information back to the network, to someone else in the network, or to any other network.

The two-way paging and messaging paradigm is divided into five levels of acknowledgement, Figure 5:

- System acknowledgement – the subscriber device acknowledges reception of an error-free message. A transparent link layer acknowledgement, between the device and the network, enables guaranteed delivery service. The network stores and retransmits messages that the subscriber device has not acknowledged.
- Message read – when a recipient reads a message, the paging device transmits a "message read" acknowledgement back to the host system or to the originator of the message.

– Canned messages – the paging device contains several ready-to-use responses, such as "Yes", "I'm ready", etc, that recipients can use when they reply to an inquiry.
– Multiple choice – the originator of a message defines several possible responses to accompany his or her message. To reply, the recipient simply selects the appropriate response.
– Editing capabilities – some devices may be used to create messages. Editing capabilities vary from device to device; for example, some subscriber devices are managed by a few simple keys and provide only minor editing capabilities; other devices contain full-feature keyboards; and still others, such as pen-based screens, receive input in other ways.

Acknowledgement levels 1 and 2 represent an exclusive one-way service that complies with the current one-way paging model; however, it may be possible to enhance the functionality of these levels to provide longer message transfer, guaranteed delivery and various other broadcast services. Acknowledgement levels 3 and 4 offer additional opportunities for simple user interaction. Acknowledgement level 5 facilitates symmetrical two-way messaging applications.

Countless applications may be supported by a pACT network, Box D. Obviously, depending on the availability of frequency spectrum, some applications are more feasible than others. For instance, operators with only a 50/12.5 kHz channel are more likely to focus on applications that do not put great demands on the inbound (reverse) channel. Similarly, a pACT network, or any other network in which available frequency spectrum is limited, is not suited to applications with high volumes of data flowing in both directions, such as file transfer.

Another consideration is maximum battery lifetime (latency) versus maximum performance. Subscribers cannot expect batteries to last in devices whose applications are optimised to respond quickly. pACT provides support for either extreme: long battery life or short response times.

## pACT system overview

The pACT system uses built-in network intelligence to manage an efficient, reliable flow of messages to and from sub-

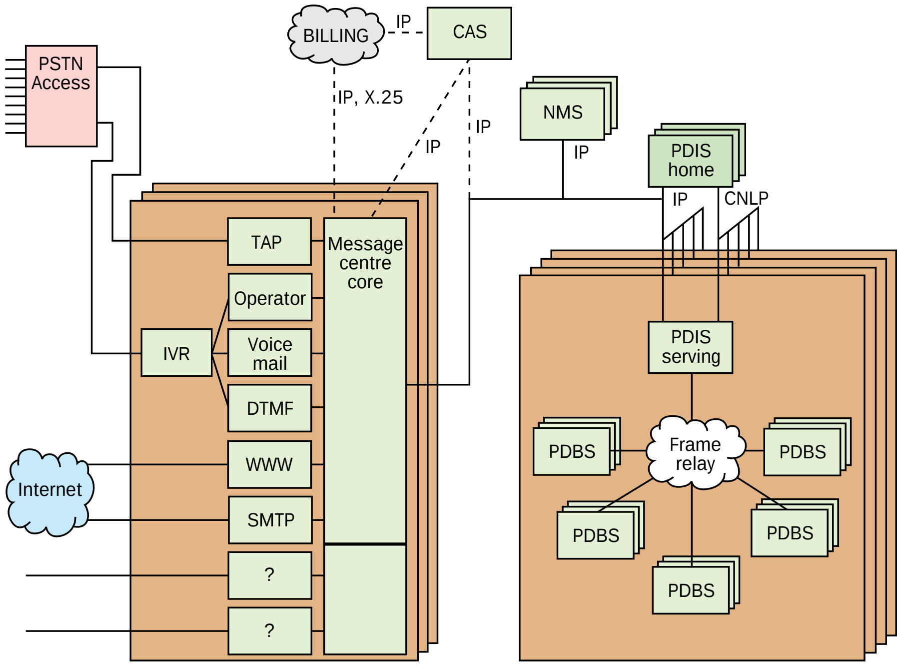



**Figure 6**
**The message centre, which is the gateway or interface to the pACT network, permits several interfaces and applications, such as Internet applications, to be implemented. A pACT network may be configured in several ways, using message centres and sub-networks of various sizes.**

### Box D Services and applications in a pACT network

**Enhanced paging applications**
– On-demand local and national news information
– Emergency updates
– Content services
  • on-demand stock and financial information
  • interactive regional movie listings, local traffic updates
  • on-demand local and national weather information
  • on-demand sports scores and other event information
  • interactive airline information, services and reservations
  • gambling and lotteries
  • geographical- and profile-specific advertising
– Acknowledgement paging with response through operators, fax, WWW, and SMTP
– Mailbox manipulation
  • remote manipulation of voice mail and fax message forwarding
  • e-mail manipulation—auto-forwarding of header/size information allows subscribers to decide whether or not to select all or part of a message
  • downloading of fax messages for display on the pager, or to another device
– Pager-to-pager messaging
– Voice paging – delivery of voice messages to pocket-size devices

**E-mail and messaging applications**
– Devices that connect to portable data terminals (laptop and palmtop computers, PDAs, etc)
– Various devices with integrated chip sets for wireless communication
– Wireless modems

**Fixed-point applications**
– Vending machine monitoring
– Home monitoring and interactive services (electricity, gas, water, air conditioning, lights)
– Generic global positioning system (GPS) services
  • location service
  • vehicle system monitoring—emergency road assistance, auto-theft prevention, SOS service
– Utility substation monitoring (interactive facilities management)
  • electricity
  • gas, water (pipe pressure)
– Environmental monitoring and large equipment monitoring (information and error reporting)
– Road and remote commercial electronic sign information updates
– Point-of-sale and mobile automatic teller machines (ATM)

**Combined asynchronous voice and data applications**
– Response with text-to-voice and text messages
– Interaction with home or office voice mail system (defined filters, priorities, etc)
– Cost-based fee notification with option to download

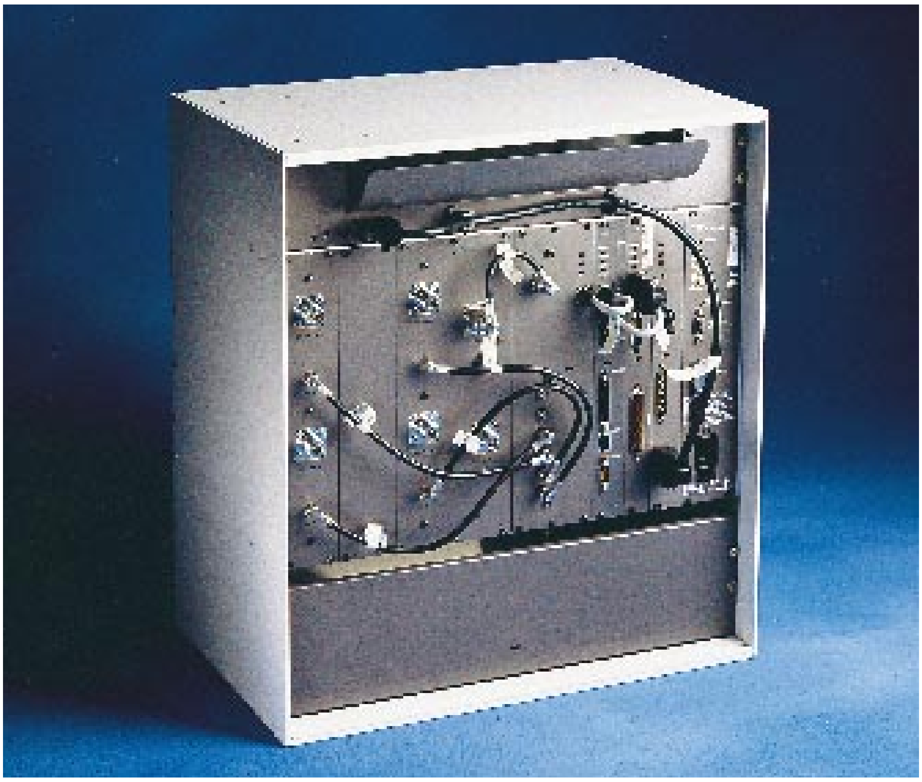


**Figure 7**
**The Ericsson RBS 540 base station for the narrow-band PCS pACT standard.**

Box E
RBS 540 technical data

| | |
|---|---|
| **Physical** | |
| Dimensions | 18.90/17.32/ 11.81 inches |
| **Weight** | 48 kg (106 lbs) |
| **Power** | |
| Power supply | 120V AC or +24V DC |
| Power consumption | Maximum 250W |
| **Radio specifications** | |
| Frequency range | RX 901-902 MHz TX 930-931 or 940-941 MHz |
| Channel spacing | 12.5 kHz |
| Receiver sensitivity (at 5% BER) with 1/3 convolutional code | –124.5 dBm |
| Transmitter output power | 55W standard (150W optional) |
| Radio data transmission | 8 kbit/s nominal |
| **Alarms** | Internal as well as external |
| **Environmental requirements** | 0 to 50°C |
| **Interfaces** | |
| Physical | V.35 |

scriber devices. Cellular radio system design and roaming techniques enable pACT to determine precisely which base station is closest to a subscriber device each time communication takes place between it and the pACT network. A key feature of the pACT architecture is that network receivers are co-located with the transmitters.

The pACT system is built from several flexible modules that can be combined and configured in different ways to meet specific operator demands, Figure 6. Because the pACT network is based on the Internet protocol (IP), operators and application providers can take full advantage of existing tools, applications, and application program interfaces (API).

pACT provides secure service, including encryption and authentication – a method which ensures that messages are delivered solely to intended subscribers.

Ordinarily, pACT data base stations (PDBS) are connected to the serving pACT data intermediate system (PDIS) switch via a frame relay network. The serving PDIS is connected to the home PDIS switch. If necessary, the two switches may be located on the same hardware platform. In addition, several other standard servers are needed to operate the network, including the network management system (NMS) and the customer activation system. The PDIS and all associated servers run on standard Sun SPARC or Sun Solstice platforms. Various configurations of computer processor power and memory are available for the PDIS, depending on requirements for computing capacity and on how the requirements relate to traffic load and the number of subscribers in the network. More computing capacity may easily be added if necessary.

The fixed entry point into the pACT network is provided by one or more message centres, which initiate, provision, and connect pACT services to public and private networks as well as to the public switched telephone network (PSTN).

## pACT system components

### The RBS 540 – Ericsson's pACT data base station

The RBS 540, Ericsson's pACT data base station (PDBS), is located at the cell site and relays data between subscriber devices and the PDIS. The RBS 540, Figure 7, is a small, self-contained full-featured base station. Thanks to its small, easy-to-manage size, the RBS 540 can be installed and put into operation in a few hours. The base station was designed for an omnidirectional site with one radio carrier, but if additional capacity is necessary, it may easily be expanded to support two or three sectors.

The RBS 540 base station was designed with an eye to helping operators to keep their operating costs low. This means that the number of base stations (cell sites) must be kept at reasonable levels. The RBS 540 supports sectored solutions with high-gain panel antennas, and up to six receivers in order to take full advantage of receiver diversity and to provide the best possible coverage from each base station transceiver (BST). An adjustable power output up to 55W is used to balance the link (two-way services), and an optional high-power amplifier (HPA) can be added, delivering up to 150W to the antenna. The pACT protocol also contains several features that increase coverage.

By means of network management, each base station is provided with a set of radio resource management (RRM) parameters. These are used to control traffic and maintain links to the network as well as to give orders to mobile terminals that access the channel. Cell transfer is determined by the mobile terminals, based on signal-strength measurements of nearby base stations.

The transceiver unit (TRX) contains a transmitter and six receivers. High sensitivity is achieved by means of six-level branch combining and maximum likelihood (Viterbi) decoding. That is, an input signal is sampled through each of six antennas (six-level branch). Discrepancies between the samples (micro-diversity) are then analysed (maximum-likelihood decoding), and a final signal is created by combining the samples' most pronounced common characteristics (maximum ratio). Three digital signal processors process the signals – one TMS320C50 and two field programmable gate array (FPGA) circuits: XC5210 and XC4025. The filter design, which provides high attenuation of adjacent bands, enables the base station to be co-located with other radio equipment. Duplex filters minimise the number of antennas that are needed. When additional transceiver units are connected to it, a single RBS 540 can support up to three independent channel streams.

The pACT data board (PDB), which controls traffic flow and handles communication with the pACT network, contains three computer processors (one MC68040 and two MC68360s). The RBS 540 contains 12 Mbyte flash memory for storing program files and 16 Mbyte dynamic random access memory (DRAM) for buffering and stack handling. A persistent management information base (MIB) stores information on the current configuration in flash memory, which enables operators to reconfigure the base station on-line.

Control of the RBS 540 is based on telecommunications network management (TNM) using the common management information protocol (CMIP). This form of control facilitates many useful functions, such as immediate alarm handling from the ALARM card. File transfer is usually accomplished by means of file transfer, access and management (FTAM) or, when in "boot mode", through the local port.

## pACT data intermediate system

The pACT data intermediate system (PDIS) acts as the central switching site in a pACT network, routing data to and from the appropriate base stations. It also maintains routing information for each subscriber device in the network. There are two versions of the PDIS: the home PDIS, and the serving PDIS. Besides switching data packets, the home PDIS maintains a location directory and provides a forwarding service and subscriber authentication. Every subscriber is registered in a home PDIS database. The serving PDIS provides message forwarding, a registration directory and re-address services. Other services or functions are multicast, broadcast, unicast, airlink encryption, header compression (to minimise airlink use), data segmentation, frame sequencing, and network management.

The Ericsson PDIS runs on standard Sun SPARC or Sun Solstice computer platforms. Thanks to high-performance capabilities (serving PDIS: 2,000-4,000 packets/second; home PDIS: 10,000-15,000 packets/second), a single switch can serve the entire pACT network, especially if the network is small or must only meet initial capacity requirements. Flexible multi-switch configurations may also be provided to meet more demanding operator requirements.

## Message centre

The message centre (MC) plays a very important role in pACT networks, initiating, provisioning and connecting pACT services to public and private networks, and to PSTN systems. Every message

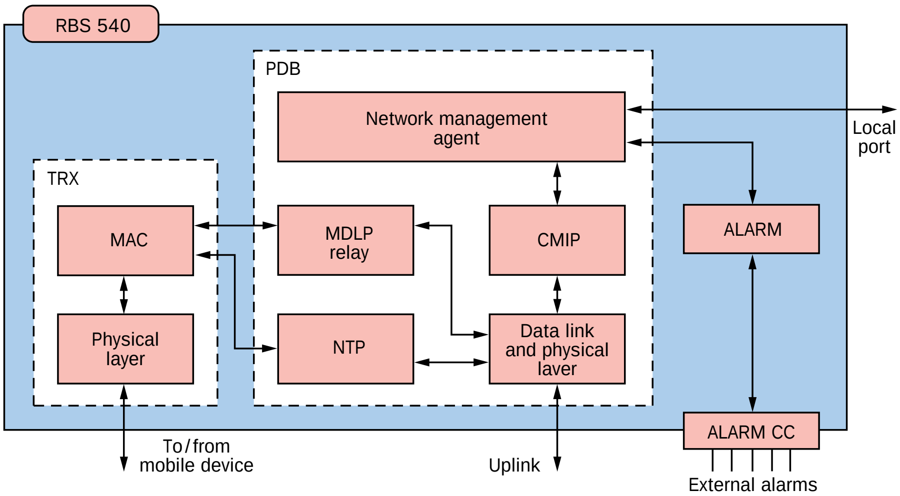



**Figure 8**
**There are basically two main parts of the Ericsson RBS 540 pACT base station:**
**- the transmitter (TRX) and six receivers for handling radio communication with advanced signal processing;**
**- the PDB, which controls the flow of traffic and communication in the pACT network.**

### Box F
### Three kinds of messaging service

**Multicast**
The serving PDIS copies a multicast message to each base station for which members have registered a specific multicast address. This service may be customised to suit specific information services or individual subscriber groups.

**Broadcast**
The serving PDIS forwards a broadcast message to every base station within a defined area.

**Unicast**
The PDIS transmits a message regardless of whether a subscriber device responds or not. This service enables a device in a reverse-channel coverage hole to receive its messages.

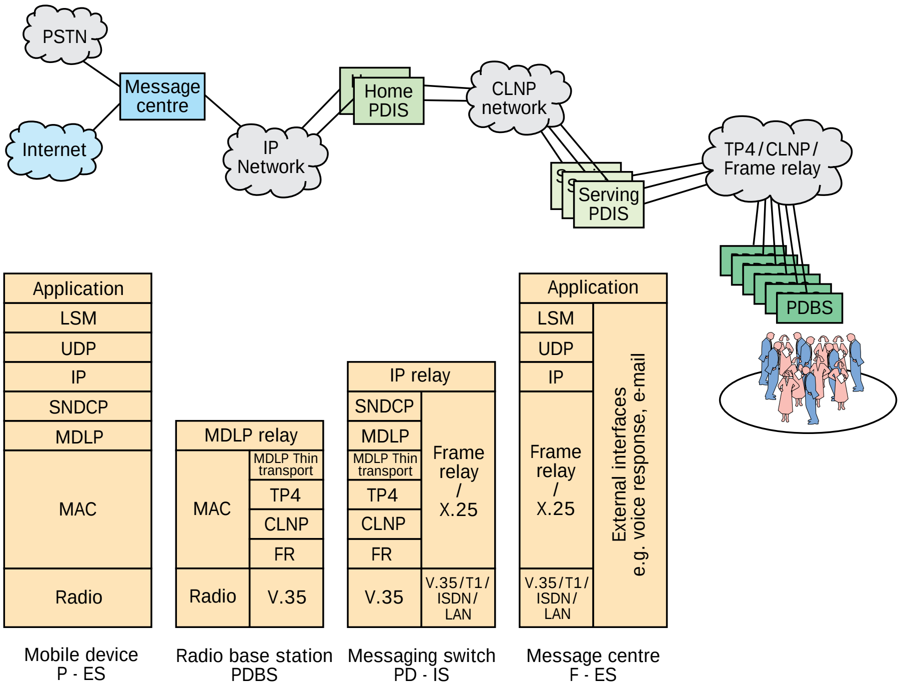



**Figure 9**
**pACT protocol stack end-to-end for two-way message traffic between mobile users and users in external networks, such as the PSTN and Internet. The pACT protocol minimises unnecessary overhead over the air link.**

passes through the message centre, whose functionality and applications vary according to network operator requirements. The core of the message centre is the message store, which handles virtually any data type and makes APIs accessible for building different kinds of applications; for example, interactive voice response (IVR), and voice or fax mail. The message store also provides functions for operation and maintenance, system monitoring, and event/alarm handling. Any of the message centre's databases can be queried via the structured query language (SQL).

The message centre also supports virtually any protocol. Typical protocols are the Internet protocol (IP), telocator alphanumeric protocol (TAP), telocator network paging protocol (TNPP), and X.400 (the ITU-T standard for message handling services).

### Network management subsystem

The pACT network management subsystem (NMS) is a comprehensive solution that gives operators full control of every component in a pACT network. Because operator requirements for use involve a variety of components and protocols, the Ericsson pACT NMS supports the common management information protocol (CMIP) and the simple network management protocol (SNMP). The NMS is implemented on a modern, distributed, multiuser network management platform called the Sun Solstice Enterprise Manager. The platform includes a graphical user interface (GUI) and several general tools for developing network management applications.

The Ericsson pACT NMS displays logical or physical components. The components are colour-coded – to help summarise the status of sub-components – and displayed in clickable on-screen areas that operators can select to access them. Thanks to the graphical interface, operators do not need to know whether components are managed by the CMIP, SNMP, or by some other protocol.

The NMS contains a database component that permanently stores parameters, configuration data, and historical records of traps and performance data. A pACT network may contain more than one NMS.

### Customer activation system

The pACT customer activation system gives pACT networks a complete account management service that enables customer service representatives to manage customer accounts and to dynamically activate pACT-related services for their customers. The customer activation system is easy to integrate into any network. Customer accounts are of two types: individual and business, where individual accounts are for single subscribers and business accounts are for multiple subscribers.

### pACT end system (mobile terminals)

Mobile terminals vary from vendor to vendor. They range from simple pagers to sophisticated two-way messaging devices such as personal digital assistants (PDAs) or palmtop computers with wireless modems/embedded chip sets. Full application support is provided for many terminals by the pACT protocol stack with the limited size messaging (LSM) protocol.

Mobile terminals periodically check the designated forward channel for incoming messages. When they are not doing this they are usually in sleep mode – in order to conserve battery life. pACT provides an enhanced flexible sleep mode – which ranges from seconds to days – with simultaneous support of devices that are just "waking up" from sleep mode. Thus, manufacturers and operators may choose between performance (highest power consumption) and latency (maximum battery life) for different classes of device and service.

**pACT system protocol stack end-to-end**

The pACT protocol stack, Figure 9, features a design that is based on concepts and principles of the CCITT-X.200 and CCITT-X.210 reference models as well as service conventions for open systems interconnection (OSI). The new LSM protocol provides the functionality of a simple e-mail application protocol, such as the simple mail transfer protocol (SMTP), but is highly optimised for low-bandwidth channels. In addition, the LSM protocol provides a platform for providing true two-way messaging and datacom services. Examples of services are embedded response messaging for simple pager devices, true two-way e-mail connectivity, and multicast and broadcast messaging. In summary, the LSM protocol provides a migration path for future applications.

To the casual observer, the network layer might resemble the standard IP design for cellular digital packet data (CDPD). However, CDPD is TCP/IP centric, whereas pACT employs a very effective user datagram protocol/Internet protocol (UDP/IP) compression technique that compresses the standard 28-byte header to a single byte for over-the-air transmission. This attribute is important for providing a short alphanumeric messaging service; for example, when the message body is roughly the same size as the header. Consequently, the maximum number of subscribers that can be supported by the system is constrained not by protocol efficiency, but by service traffic. CDPD uses RFC-114, which is a technique for compressing the standard 40-byte TCP/IP header to an average of 3 bytes.

pACT's sub-network convergence layer provides an important new approach to encryption. To ensure that airlink bandwidth is not spent on resynchronising the encryption engines, pACT devices may employ a technique that automatically resynchronises the engines, even when the underlying layers fail to deliver a packet. This technique is important because it provides a mechanism by which multicast and broadcast services may be encrypted.

The CDPD link layer is optimised for duplex, whereas pACT uses two-way simplex. The pACT mobile data link layer protocol (MDLP) is an enhanced version of the link access procedure on the D-channel (LAPD), see CCITT Q.920, which allows subscriber devices to adopt strategies for auto-link reset and optimised power saving.

## pACT airlink interface

The pACT backbone network is quite similar to a regular CDPD network. The main differences between the two involve functionality – mostly for extending battery life

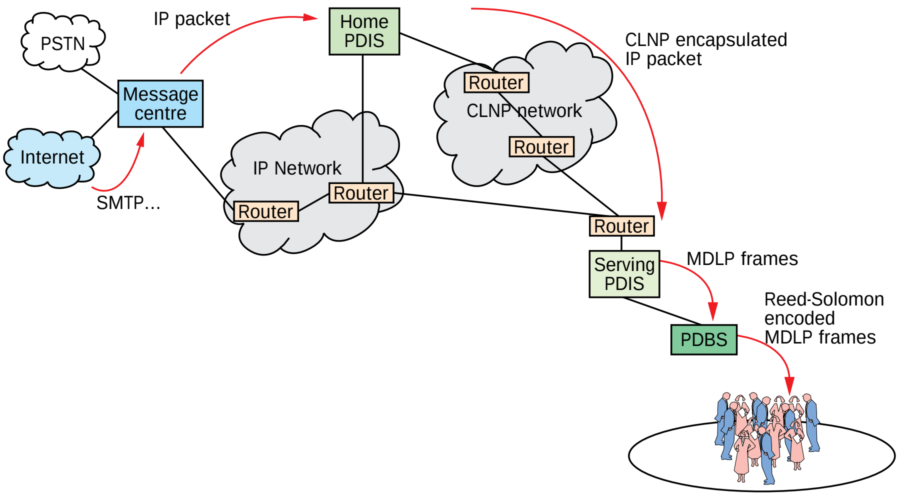



**Figure 10**
**Network traffic flow – to mobile subscribers. A message is always routed via the home PDIS to the serving PDIS, which then delivers the message to the cell (base station) in which the subscriber is located.**

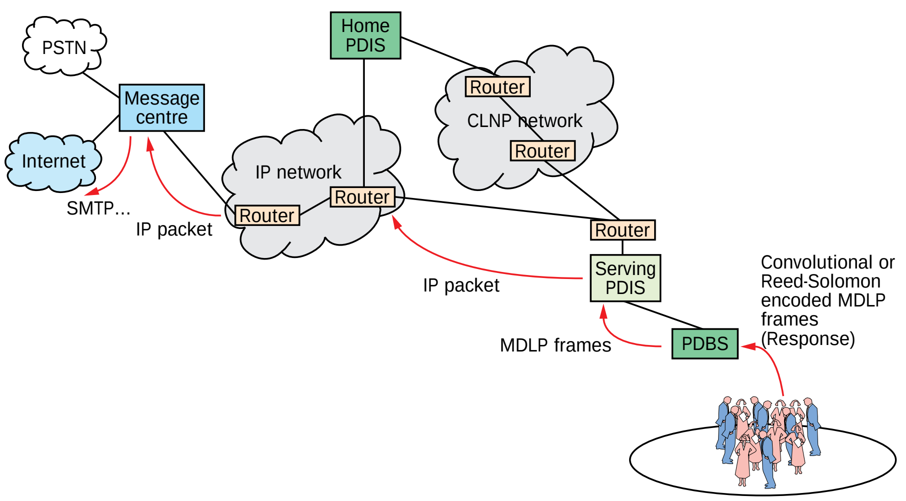



**Figure 11**
**Response traffic flow – from mobile subscribers. A message is routed via the serving PDIS to the appropriate message centre.**

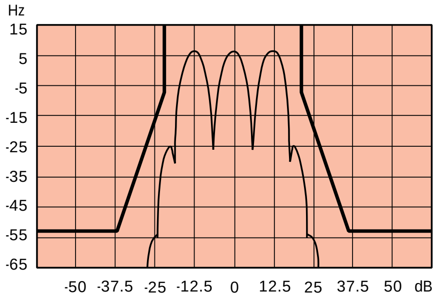



**Figure 12**
**pACT power spectral density of the three most powerful carriers in a 50 kHz channel for GMSK sources: 3 x 50 W, 8 kbit/s, 2-level, BT = 0.5, h = 0.5.**

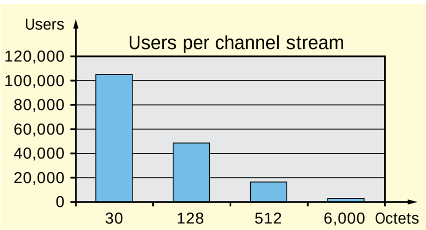
Box G
Example of capacity

Assumptions:

| | |
|---|---|
| Busy hour call rate | = 25% |
| Channel | = 50 kHz/50 kHz |
| Base stations | = 100 |
| Reuse pattern | = 12 |

Subscribers unevenly distributed in the coverage area. Approximately 1,900,000 subscribers (average message length 30 octets) or approximately 25,000 subscribers (average message length 6000 octets, voice messages approximately 40 seconds).

**Figure 13**
**pACT single radio channel stream capacity. Busy hour call rate is 25%.**




in subscriber devices – and features such as group messaging, broadcast, and unicast. Despite the similarity, however, the pACT air interface really does not compare with CDPD. The air interface was developed with very stringent device requirements in mind. While the CDPD air interface was optimised for standard IP-based applications, the pACT protocol shortens and reduces the number of transmissions and contains an efficient sleep mode for conserving batteries. Moreover, although base station power may be 100 times higher than mobile terminal power, which is typically less than 0.7 W, the pACT performance specification enables operators to balance the forward and reverse link coverage.

A 50 kHz channel may accommodate up to three individual radio frequency (RF) carriers. Each base station is assigned a particular 12.5 kHz channel. pACT also supports time slot multiplexing (TSM), which means that in addition to its distinct radio frequency, each base station is assigned a duty cycle and repetition state. The duty cycle and repetition state fulfil requirements for the reuse pattern which, in turn, meets the criteria of the carrier-to-interference ratio. Typical reuse patterns are 9:1, 12:1 and 15:1. An operator with two adjacent 50 kHz channels may drop the guard band (6.25 kHz) to pick up an extra RF carrier – for a total of seven RF carriers.

The airlink interface uses Gaussian minimum shift keying (GMSK) modulation. The both-way trunk (BT) value is 0.5, with a symmetrical transmission speed of 8 kbit/s in both directions. (The BT value is 0.3 for uplink in single 12.5 kHz configurations.) Reed-Solomon (63.47) coding is used on the forward link, and convolutional coding (2/3, 1/2, and 1/3) is used on the reverse link (variable-rate Viterbi coding).

The three-level convolutional coding, which is a major feature of the pACT air interface, is connected to the subscriber device power-control feature. Together, the two play an important role in increasing base station coverage: the coding levels make it possible to trade capacity for reliable transmission capabilities (increased coverage) at the outer fringes of the cell. Power control management helps reduce substantial losses in capacity, especially in cells with heavy traffic loads.

The raw bit rate is always 8 kbit/s in each direction. When a mobile terminal is close to the base station and has a very good radio path, it uses minimum output power and as few coding bits as possible (2/3). As the mobile terminal moves away from the base station, the transmitting power level is gradually increased until it reaches the maximum level allowed. From that point on, nothing more can be done to sustain coverage, except perhaps to add more coding bits in the transmission frames.

Coding bits are added in two steps: "more coding bits" (1/2), followed by "most coding bits" (1/3). Adding coding bits in the transmission frames has the same effect as lowering transmission speed – in either case capacity is traded for coverage. pACT does not trade capacity for coverage unless absolutely necessary. Operators who want to maintain symmetrical throughput in a network or in a particular area do so by building dense networks, where subscriber devices are able to register with another base station before coding bits must be added in order to sustain coverage.

The cellular design of the pACT network enables network operators easily to add capacity where it is needed most. Operators may either split the cells of heavily loaded base stations, or add more base stations.

## pACT economics

As with any two-way infrastructure, pACT is more expensive to deploy and operate than regular simulcast-based one-way systems. In order to provide end-users with transparent service offerings, two-way paging devices will most likely require some kind of operator subsidy. That is, based on individual operator requirements and market-specific price levels, operators should anticipate investing 3-7 times as much to deploy a two-way network – which provides the same coverage as a one-way network – as they would to deploy the one-way network. Similarly, operators should expect to pay 5-8 times as much to operate a two-way network. Nonetheless, thanks to the tremendous gains in capacity that are won by the two-way infrastructure, operators are able to serve more subscribers at a lower cost per subscriber.

In two-way systems, a much larger customer base is required to yield a lower average cost per subscriber than the lowest cost per customer in a one-way system, Figure 14. Operators of a two-way infrastructure who exceed this critical point have a distinct competitive advantage. Not only are these operators able to provide one-way paging services for less than their competitors, but they are also able to reap new revenues, by providing new and enhanced services via the same network infrastructure.

There are two basic reasons for investing in a two-way infrastructure:

– Operators need to increase the capacity of geographically large one-way systems without adding frequency spectrum.
– Operators want to provide customers with new or enhanced services.

Small, local operators whose sole objective is to provide regular one-way services in countries or regions where frequency spectrum is not limited are unlikely to benefit from investing in two-way technology.

With the introduction of broadband PCS into the cellular industry, pricing is likely to fall dramatically in coming years. Monthly cellular billing charges will drop to new lows, and the price of basic paging services, which is already quite low, will also continue to fall. The current price differentiation will most likely diminish but not disappear altogether.

## pACT Vendor Forum

pACT has received a great deal of attention from the paging industry. Just months after the pACT Vendor Forum was formed in April 1996, more than 30 companies had joined it, including AMD, AT&T Wireless Services, Cantel, Casio, Ericsson, IBM, LanSer, NEC, Panasonic, PCSI, Retix, SEMA Group, Sharp, and US Robotics.

In its charter, the pACT Vendor Forum states that its role is to enable worldwide support for, and to promote the adoption of, the pACT two-way narrowband PCS standard. Forum members are dedicated to the rapid development of a variety of pACT products and services that are designed for open systems, and that ensure multi-vendor compatibility and interoperability. Membership is open to any vendor, or prospective vendor, of products or services that comply with the pACT standard.

## Conclusion

Despite the introduction of packet data services and short message services in various cellular technologies, multi-service platforms cannot be optimised for every target group. Dedicated networks for packet services still play an important role, and narrowband networks and related services will continue to emphasise their particular strengths. In head-on competition, cellular providers will find it difficult to compete with the low cost, small device size, long battery life, and low monthly service fees that paging services offer.

pACT is primarily intended for the North American narrowband PCS market. However, pACT will work in any frequency band that is set aside for two-way paging and messaging services. Besides pACT, other protocols for the narrowband PCS frequencies include the family of FLEX protocols from Motorola.

pACT increases capacity by reusing frequencies. By combining this feature with high airlink speeds, operators can increase capacity in a large zone 100-200 times – even more in networks that consist of several zones.

The pACT system is built from several flexible modules that can be combined and configured in different ways to meet specific operator demands. Because the pACT network is based on the Internet protocol, operators and application providers can take full advantage of existing tools, applications, and APIs. pACT also provides secure service, including encryption and authentication. Very few systems can provide millions of customers with the same cheap, easy-to-use service as pACT, especially when applied to a total channel bandwidth that is measured in kHz.

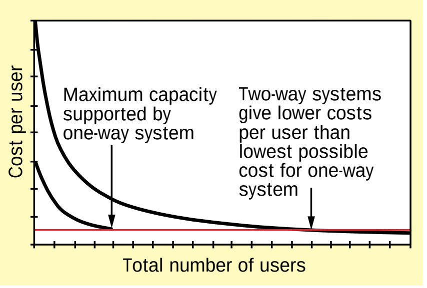



**Figure 14**
**Comparison of network operator costs per subscriber for one-way and two-way systems.**


## References

1 pACT Specification, Release 1.1, October 1995, AT&T Wireless Services.
2 pACT 97 specification. Ericsson, PCSI and Datum Telegraphic
3 RBS 540 Product Description. Ericsson Radio Messaging.
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