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IVOX - The Interactive VOice eXchange Application

R. Brian Adamson
NEWLINK Global Engineering Corporation

Joseph P. Macker
Naval Research Laboratory
Information Technology Division

INTRODUCTION

This report describes the design and development of the Interactive VOice eXchange (IVOX) computer software application. IVOX provides real-time interactive voice communication over computer data networks. IVOX uses advanced voice compression techniques to maintain very low data rates. The low data rate feature of IVOX allows useful voice communication over existing computer network connections without a significant impact on other data communications (e.g., email, file transfer). IVOX provides a simple graphical user interface for call setup and management. IVOX allows for cross computer platform interoperability with versions for Sun SPARCStation, Silicon Graphics, and Hewlett Packard workstations. Support for Digital Equipment Corporation (DEC), Apple Macintosh, and Microsoft Windows platforms is in development [1].

BACKGROUND

Digital voice communication systems have typically required dedicated allocation of communication resources and bandwidth separate from those used for other data communication (e.g., tactical data, messaging). Often, those dedicated resources go unused during periods of low demand for voice communication. Open systems computer internetwork technology with protocol stacks such as the Transmission Control Protocol/ Internet Protocol (TCP/IP) suite has made it possible for a large number of users to efficiently and dynamically share heterogeneous communication media and networks [2]. The practical, flexible resource sharing and utilization capabilities presented by this technology offers advantages for Navy communications and is being applied to provide a general purpose data communication service [3]. It is possible to support useful voice communication over computer data networks given sufficient data throughput capacity, acceptable data delivery latency at the link layer, and proper application design [4]. Integration of voice communication services along with other data services offers the following advantages.

1) More efficient utilization of available limited communications bandwidth and resources.

2) Reduced need for multiple communications management systems.

3) Potential for integrated multimedia computer applications to support distributed mission planning and execution. (e.g., distributed interactive conferencing and presentation systems)

4) Lower communication resource cost by reducing the need for dedicated, leased voice coordination circuits (e.g., INMARSAT channels).

The NATO Communication Systems Network Interoperability (CSNI) [5] and the NRL Data and Voice Integration Advanced Technology Demonstration (DVI ATD) [6, 7] projects developed and demonstrated network architectures supporting integrated digital communication services (including voice) with application of open systems network protocols and technology. The network connectivity provided by these research projects consists of low data rate, radio frequency (RF) communication links. Both projects made use of connectionless, packet switched routing and data delivery protocols. CSNI utilized the International Standard Organization (ISO) Connectionless Network Protocol (CLNP) stack and the NRL DVI ATD used the TCP/IP protocol stack.

Some experimental and commercially available computer applications have been developed to provide voice communication over connectionless computer networks (e.g., InPerson, ShowMe, Visual Audio Tool (vat), Network Voice Terminal (nevot)). However, the use of relatively high data rate voice coding within these existing network voice applications places unnecessary demands on performance and limits participation for mobile users and network sites with relatively low bandwidth resources such as found in many tactical communication systems. Applying adaptive, low rate compression algorithms to network voice communications is an enabling technology for users with low bandwidth resources and enhances the performance of higher bandwidth systems under loaded conditions. This is the fundamental principle followed in the development of IVOX; use of advanced low data rate voice compression and use of open systems computer network protocols.

Network Voice Delivery Requirements

There are some fundamental differences between the synchronous, dedicated communication channels typically used for digital voice communication and the data delivery service provided by connectionless network protocols. These include:

Error handling:
  Bit error rate vs. packet drop rate

Communication delay:
  Deterministic vs. non-deterministic delay

• Data delivery:
  Synchronous bit stream vs. asynchronous packets

Error Handling

Previous digital voice communication systems integrate robust error handling within the speech coding algorithm because the voice terminal application has had direct access and control of the physical communication media. In contrast, the application layer within connectionless datagram networks maintains independence from the underlying communication media. In a global internetwork, this independence allows applications to communicate peer-to-peer across multiple, heterogeneous media. Lower layer protocols at the transport, network, and link layers usually assume the major responsibility for any error handling. Datagrams in error are either automatically retransmitted or dropped depending upon the protocol set used. As a result, the application layer (i.e. the voice terminal in our case) does not usually incur bit errors in its communication data stream but will need to be able handle undelivered packets and reconstruct packet ordering. IVOX is designed to appropriately handle and recover from dropped data packets and reorder received packets as necessary.

Communication Delay

Dedicated connection oriented communication channels can provide deterministic delay in the delivery of voice data. With connectionless datagram delivery, there can be a significant amount of nondeterministic variance in the inter-arrival times of data packets. Furthermore, it is possible that data packets are received in a different order than they were transmitted. Current Internet Protocol (IP) service provides "best effort" delivery where all data flows are given the same quality of service (QoS). Research is being conducted and initial test systems are in place for standardized IP routing and data delivery techniques that bound factors affecting quality of service such as delay variance[8, 9]. Such vendor-independent resource management techniques will provide proactive internetwork bandwidth allocation among and between application data streams. Until techniques are widely implemented throughout the Internet, for many media, the "best effort" service model can continue to provide adequate service for even real-time applications such as digital voice communication. IVOX has been designed and tested using network architecture with and without QoS and resource reservation capability.

Data Delivery

Current digital voice communication systems generally provide continuous synchronous delivery of voice data across a dedicated communication channel. The dedicated communication channel is typically designed to provide a fixed amount of bandwidth, and vocoding algorithms have been designed to provide the best voice quality for bit rates supported within this bandwidth. In the connectionless networking environment where communication bandwidth is dynamically shared in an asynchronous fashion among distributed users and applications, adaptive rate voice coding techniques (e.g., silence detection) can improve bandwidth utilization dramatically. Adaptive rate voice coding can allow for high voice quality while maintaining a lower average network throughput requirement. The synchronous nature of many current voice encoding schemes has led to a widespread perception that voice communication requires "stream" oriented data communications when the information content of conversational voice is actually bursty in nature. This low data rate, bursty source can be serviced effectively by an asynchronous, connectionless network fabric. In IVOX, NRL has utilized an adaptive rate enhancement to existing DoD voice digitization algorithms and uses this as the primary mode for network voice communication [10].

DESIGN

The design of IVOX was conducted with the features and limitations of network data services in mind. In particular, the additional limitations imposed by low data rate tactical connectivity were given special consideration. The following is a list of design goals for IVOX.

1) Use existing computer platforms without modification.
2) Provide a simple graphical user interface with familiar telephone call paradigm.
3) Robust and efficient call setup and management protocol.
4) Provide multiple data rate vocoder algorithms for multiple levels of voice quality and capability of operation over a wide range of network connections.
5) Modular software design for easy integration of additional vocoders and other features.
6) Multiple modes of operation (e.g. half-duplex/ full-duplex, real-time/ non-real-time).
7) Flexible set of user controllable parameters for evaluation over different data networks.

Overview of Operation

IVOX digitizes voice using the computer's built-in audio hardware and then, using specialized speech encoding algorithms, compresses the audio data to continuous data rates as low as 600 bits-per-second (bps). Additionally, IVOX employs a silence detection technique to reduce the average data rate to even lower rates. For example, IVOX uses the Federal Standard 1015 Linear Predictive Coding (LPC) speech compression to achieve a data rate of 2400 bps. With silence detection removing the gaps between words or during pauses in speech, the typical measured data rate

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