Voice-over-IP (VoIP)

Overview

- VoIP Introduction
- Basic PSTN Concepts and SS7
- Old Private Telephony Solutions
- Internet Telephony and Services
- VoIP-PSTN Interoperability
- IP PBX
- Network Convergence
- Technology Comparison
- VoIP Signaling Protocols
- SIP
- ENUM

VoIP Introduction (1/2)

- Voice becomes another Internet application
- The VoIP model is similar to the Web (and email) model
- VoIP signaling is a value-added service
  - VoIP signaling supports both centralized and distributed architectures
  - Can signaling be kept inside the carriers’ networks?
  - Where can carriers benefit?
- Important economic issues with VoIP
  - Low cost of entry
  - How can carriers maintain competitive position?

VoIP Introduction (2/2)

- VoIP is relevant to both the **wide** and **local** area
  - Toll bypass and IP PBX/Centrex
- VoIP can offer novel telephony services in addition to voice
- It coexists with legacy telephony
- It is based on open standards
  - Numerous vendors of services and equipment: competition, choice, and faster development of new services
- VoIP ultimate goal: global, low-cost, unified communications
The Old Approach

PSTN / SS7 Operation

The New Approach

Internet Telephony

- IP as the transport protocol for both media and signaling
  - Media: Packetized voice instead of TDM virtual circuits
  - Signaling: Internet protocols instead of SS7 and proprietary PBX protocols
- Programmable servers, open APIs, third-party services
  - Instead of "closed" switches and PBXs
Why IP-Based Communications?

- Efficient use of link bandwidth
  - Statistical multiplexing
- Fault tolerance
  - Per-packet routing
- Wide-area infrastructure available
  - Optical core, currently over-provisioned
- Economic reasons
  - Easier to manage, uniform technology

PSTN Interoperability (1/2)

- Interoperability remains a key issue
  - The PSTN and SS7 will not go away soon
- Introduce PSTN-VoIP gateways
  - Devices that translate both media and signaling traffic between the PSTN / SS7 and IP networks
  - Gateways are connected to both the PSTN and to an IP network
  - Gateways are critical resources
    - Limited number of PSTN lines per gateway → limited concurrent PSTN sessions
    - PSTN access → PSTN billing → Cost for the gateway’s owner
    - Potential targets for Internet hackers

PSTN Interoperability (2/2)

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The IP PBX

- The IP telephony equivalent of the PBX
  - An example of voice/data network convergence
  - Uses IP over Ethernet to provide local telephony services
**IP PBX Components**

1. A VoIP-aware Ethernet switch
2. A Signaling Server
   - Can be a standard PC, but more specialized devices also exist
   - Cheaper, easier to configure, maintain and upgrade compared to a PBX box
3. Terminals
   - Connect to the Ethernet network
   - Multimedia PCs can also be used as terminals
4. A PSTN gateway

… and a signaling protocol to manage the sessions

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**Network Convergence**

Interoffice Communications: Before and After Convergence

**Internet Telephony: signaling**

- **Signaling Requests**
- **Signaling Responses**
- **Media**

VoIP Signaling Protocols

- **H.323**: the ITU’s IP-based signaling protocol
  - Initially designed to be carrier-friendly: centralized intelligence
  - Assumed dumb terminals
  - Modeled after existing PSTN / ISDN signaling protocols
  - Carrier-centric, enables carriers to have greater control

- **SIP**: the IETF’s IP-based signaling protocol
  - Initially designed to be user-friendly: edge intelligence
  - Assumed smart terminals
  - Modeled after existing Internet protocols (HTTP, SMTP)
  - User-centric, leverages other Internet protocols (lightweight protocol)
SIP - General

- IETF’s Session Initiation Protocol
  - Used to initiate, modify, and terminate multimedia sessions
    - Sessions can be two-party or multiparty
    - Sessions may include advanced services
  - A text-based, client-server protocol similar to HTTP and SMTP
- Main SIP entities
  - User agents (the software that runs on a client device)
  - Proxy and redirect servers
  - Registrars
  - Location servers
  - Feature servers (supporting voice-mail, presence, gaming, etc.)

SIP – Typical Call Setup

1. A request is sent (SIP INVITE) to INITIATE a session
2. DNS Query for the IP Address of the Destination Domain
3. The INVITE is forwarded
4. The Location Server is being queried to check the (current) destination IP address of the callee's User Agent
5. (Inbound) Proxy
6. The request is forwarded to the End-Device
7. Destination device returns its IP Address to the originating device and a “direct” media connection is opened

SIP – Presence and Instant Messaging

- Presence server
- SUBSCRIBE
- NOTIFY
- Proxy
- subscribe
- notify
- Peter
- Linda
- Presence
- Server
- telcordia.com
- Proxy
- SUBSCRIBE peter@telcordia.com
- telcordia.com

SIP – Calling a Roaming User

- Home Network
- Cell 2
- Cell 1
- FP
- HP
- INVITE
- INVITE
- INVITE
- Signalling Data
### Advanced Services with SIP

- **Device independence example**
  - A user binds his SIP URL to his home phone, his office phone, and his mobile phone (or his hotel room phone when traveling)
  - Incoming calls ring all devices and user picks up the one that is closest

- **Voice-mail notification example**
  - Callers can be redirected to voice-mail after a user-specific timeout
  - The inbound proxy can send an SMS or e-mail notification to the callee

- **Smart screening example**
  - User agents (or proxy servers) can be configured to screen incoming calls
  - Calendar integration can enable smart, time-of-day call routing

- **Text-to-speech example**
  - Proxies can use text-to-speech to read to users their urgent e-mail

- **Forking example**
  - Proxies can “fork” a call addressed to a virtual endpoint (e.g. to `sip:sales@company.com`) to all the devices used by sales staff
  - The first one to answer “wins”

### ENUM

- **IETF’s E.164 Number Mapping Protocol**

- **ENUM: one number for all services**
  - Given a E.164 number, find additional contact information for this number (such as email addresses, web URLs, fax numbers, SIP URIs)
  - “Only one number printed on business cards”
    - If the user changes Internet providers he can keep the same number and only inform an **ENUM registrar** of his new email address and web URL
  - Companies with “unfortunate” domain names can potentially rely only on a well-known 800 number

- **ENUM assumptions**
  - People are used to phone numbers
  - 12-key communication devices are still common
• Resolve a E.164 number to a list of URIs using the DNS
• “telephone number in, URI out”
• Special blocks of E.164 numbers can be allocated for ENUM
• ENUM DNS records can contain a list of:
  - E-mail addresses
  - Fax numbers
  - Website URLs
  - SIP URLs
  - Instant Messaging screen names
  - Other E.164 numbers (such as landline or mobile numbers)

• Ownership, regulation, jurisdiction, and international law issues

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**ENUM (4/5)**

• How does ENUM work?
  - Assuming appropriate ENUM client and server software:
    1. The user starts up an e-mail, web, or other Internet client
    2. Enters a local or international phone number in the address field
    3. The built-in ENUM client transforms the number into a fully qualified E.164 (usually by adding country and area codes)
    4. The ENUM client reverses the number, places dots between each digit, and appends the ENUM top level domain name 'e164.arpa'
      - This reversal is required because E.164 numbers and the DNS nest administrative domains within other domains in different order (right-to-left for E.164, left-to-right for the DNS)
    5. An ENUM DNS query is issued
    6. The resulting URI(s) (e-mail addresses, web URLs, etc.) can be used by the Internet client, depending on (1) the client type, (2) user preferences and (3) registrant priorities

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**ENUM (5/5)**

**Example #1**
**ENUM Lookup**

1. DNS Query
2. DNS URI response

8.7.6.5.4.3.2.1.2.1.6.e164.arpa

1. sip:gilh@sip.telstra.net
2. tel:61412345666
3. tel:61212345666

**Example #2**
**ENUM Fax**

IP Fax Call to
+61 2 12345678

1. sip:gilh@sip.telstra.net
2. mailto:gilh@telstra.net
4. fax:61264486165
5. imm:gilh@irc.telstra.net
6. tel:61412345666
7. tel:61212345666

Initiate PSTN session
To +61 2 62486165