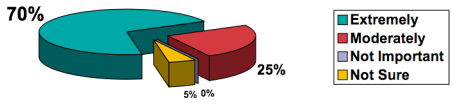
SIP SECURITY

**AUTHENTICATION,
ENCRYPTION,
IDENTITY**

Cullen Jennings, PhD
fluffy@cisco.com

Does Anyone Care?

To what extent is the relative security of an IP telephony solution important within your purchase decision?



Source: Cisco Systems survey, April, 2004

Secure SIP Systems

Agenda

Cisco.com

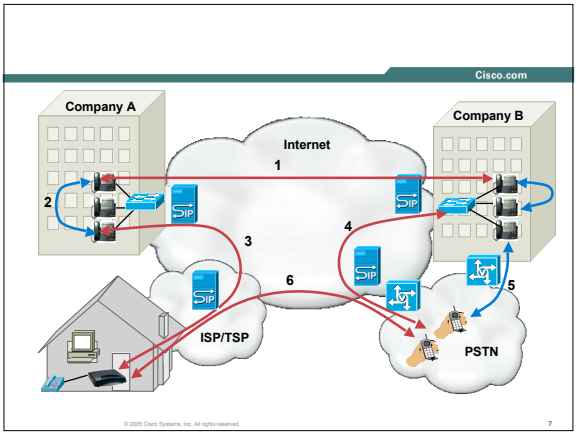
- This talk is about the protocol security in VoIP
  - Introduction to SIP
  - Threats
  - Channel Security
  - Object Security
  - Media Security
  - Certificate Management
  - State of Implementations & Standards

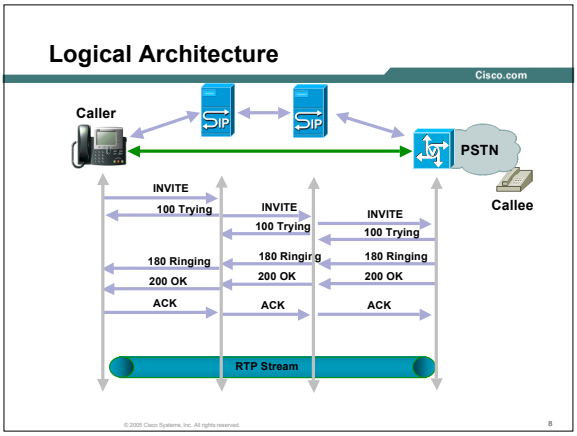
THREAT MODEL

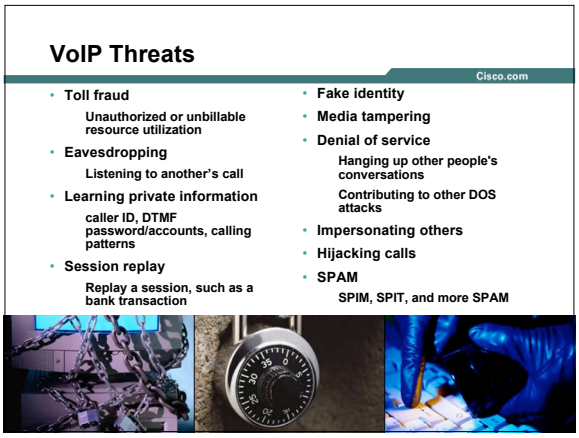
SIP Introduction

Cisco.com

- Used for Voice and Video over IP
  - Toll Arbitrage
  - Residential / IpCentrex
  - Enterprise / IpPBX
- SIP/SIMPLE for Instant Messaging
- Used for Application, Whiteboard, and Web sharing
- How SIP works
  - Peer to Peer System
  - Rendezvous points to find others
  - Separation of media and signaling
  - Negotiation of rich media







Why SIP Security is Hard

Cisco.com

- SIP is a rendezvous protocol, communicates with peers in any domain with no previous security relationship
- Deals with multiple intermediaries and endpoints with different trust for each (need both channel and object security)
- Multiple endpoints can be involved (eg. forwarding, forking, conferencing, transfer)
- Supports anonymity, call trace, legal intercept, and privacy (simultaneously)
- Complicated by: NATs, firewalls, high reliability, large scale, choice of transport protocol (eg. TCP, UDP, TLS, SCTP, DCCP)

On Path / Off Path

Cisco.com

- On Path Attacks:
  - An attack that is only possible when the attacker can control one of the network elements or connections over which the the call traverses
- Can be prevented by controlling access to the network component

- On path DOS attacks are well known and uninteresting

Solutions to Threats

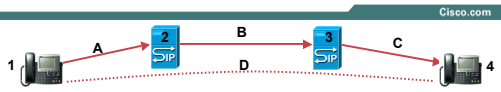
Cisco.com

- Authentication/Authorization from:
  - client to server
  - server to server
  - server to client
- Privacy and integrity hop by hop (Channel Security)
- Privacy and integrity end to end (Object Security)
- Client and server assertion of user identity (can be different)
- Server removal of identity for anonymous calls
- End to end assertion of identity
- Signaling end to end integrity and privacy
- Media end to end integrity and privacy

AUTHORIZATION & AUTHENTICATION

Authentication & Authorization

Cisco.com



- Authentication - Who sent me this?
  - over link A: Proxy checks the user (Digest or mutual TLS)
  - over link B: Proxies check each other (mutual TLS)
  - over link C: UA may verify request came from "its" proxy (TLS)
  - end to end (D): UAS may verify UAC (SMIME)
- Trust is not transitive: even if 1 trusts 2 and 2 trusts 3, it does not follow that 1 trusts 3
  - MCI might carry Vonage calls - Cullen has an account with Vonage, but MCI does not have any trust relationship with Cullen

Digest Authentication

Cisco.com

- Can only challenge a request from UA to Proxy
  - UAC to UAS is possible but seldom used
- Used to authenticate for requests such as outbound calls
- Used to authenticate for requests such as registration for inbound call
- Does not work proxy to proxy
- About the same as a HTTP Digest authentication from web browser to web server

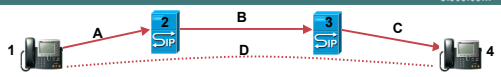
TLS Authentication

Cisco.com

- The certificate in SIP TLS asserts the DNS name of the host
- This is in the Subject Alternative Name field
- Phones typically don't have a stable DNS name and don't have a certificate that can be used for TLS
- Mutual TLS is useful for proxy to proxy authentication
- Devices that do TLS need to have a Root Trust List compiled in. It must be possible to replace this with a customer specific list
- Session resumption mode is critical for avoiding "Start of Service" avalanche restart problem

Encryption and Integrity

Cisco.com



- Follows the web model and uses TLS on a hop by hop basis
- Follows the email model and uses S/MIME on end to end basis
- TLS creates an authenticated, encrypted, integrity-checked channel
  - Crypto generally: RSA, 3DES or AES, SHA-1
- Use S/MIME to sign and encrypt portions of the SIP body
  - Crypto generally: RSA, 3DES (moving to AES), SHA-1
- Use SRTP to protect RTP/RTCP media (audio, video)
  - Crypto generally: AES-CM, SHA1

IDENTITY

Identity

Cisco.com

- Goal is to understand who are you communicating with
- Requires strong cryptographic assertions
- Represents the most promising approach for dealing with SPAM, SPIM, and SPIT
  - White lists
  - Reputation services
- Needed for B2B and B2C transactions

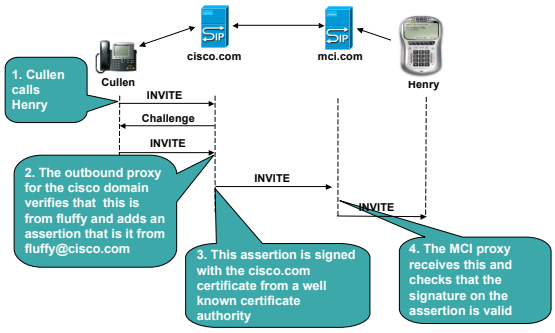
Who is fluffy@cisco.com

Cisco.com

- Who is in the best position to make strong assertions about who fluffy@cisco.com is?
  - Cisco.com allocated the address fluffy to Cullen
  - They provided a way for Cullen to prove his identity with logon password, secure token card, etc.
  - Having Verisign assert that some random person can receive email sent to fluffy@cisco.com is a weak assertion of identity
- Who knows who cisco.com is?
  - Verisign can verify with DNS registrars who has been given that name and can get appropriate contacts for it

Identity Service for SIP

Cisco.com



Signed Portion of Message

Cisco.com

```
INVITE sip:bob@biloxi.org SIP/2.0
       Via: SIP/2.0/TLS pc33.atlanta.com;branch=z9hG4bKnashds8
       To: Bob <sip:bob@biloxi.org>
       From: Alice <sip:alice@atlanta.com>;tag=1928301774
       Call-ID: a84b4c76e66710
       CSeq: 314159 INVITE
       Max-Forwards: 70
       Date: Thu, 21 Feb 2002 13:02:03 GMT
       Contact: <sip:alice@pc33.atlanta.com>
       Content-Type: application/sdp
       Content-Length: 147

       v=0
       o=UserA 2890844526 2890844526 IN IP4 pc33.atlanta.com
       s=Session SDP
       c=IN IP4 pc33.atlanta.com
       t=0 0
       m=audio 49172 RTP/AVP 0
       a=rtpmap:0 PCMU/8000
```


Identity Headers

Cisco.com

- **Identity is SHA1 hash with RSA signature**

```
Identity:
  "CyI4+nAkHrH3ntmaxgr01TMxTmtjP7MASwliNRdupRI1vpkXRvZXx1ja
     9k0nB2sW+v1PDsy32MaqZi0M5WfEkXxbgTnPYW0jIoK8HMyY1VT7egt0kk4
      XrKFCHYWGClsM9CG4hq+YJZTMaSROoMUBhikVIjnQ8ykeD6UXNOyfI="
Identity-Info: <https://atlanta.com/cert02.cer>;alg=rsa-sha1
```

- **Extensible to other algorithms with additional header**
- **Identity-Info is place TLS connection can be formed to fetch certificate**
- **Can migrate to DNS Sec**

Signature Assertion

Cisco.com

- **The authentication service authenticates the UA and validates that the UA is authorized to populate the value of the From header field**
- **The authentication may happen by sending a Digest authentication challenge**
- **The value of the From header field may be the user's AoR, or it may be some other value that the policy of the proxy server permits the UA to use**

Results

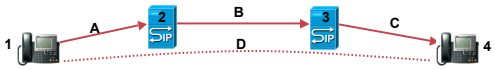
Cisco.com

- Caller ID that works (unlike PSTN)
- Enterprises and service providers need one web server style certificate rather than one certificate per user
- White lists can authorize communications with people we talk to frequently
  - Address books and buddy lists are examples of white lists
- Communications with new parties can benefit from
  - reputation services
  - friend of friend introduction services
  - social networking systems
- Reduction of SPAM/SPIM/SPIT

CERTIFICATES END TO END ENCRYPTION

Object (End to End) Security

Cisco.com



- Use S/MIME to sign and encrypt portions of the SIP body
- Protect private information from intermediaries
- Assertion of far end identity in a certificate
  - Know who you end up communicating with
- Before saying S/MIME was a failure ….
  - It has been widely implemented, it works, security is good. Technically works well. Deployment is sparse but this relates to the difficulty and cost of an end user getting a certificate. More on this later…
- Crypto generally: RSA, 3DES (moving to AES), SHA-1

Certificates for Encryption

Cisco.com

- SIP needs certificates for end to end encryption
- Can use traditional capital "PKI" certificates (like Verisign)
  - Problem: enrollment is difficult and expensive
- Can use private CA signed certificates
  - Problem: only works in limited trust domain. Can't get others to use this CA root as a trust anchor
- Can use self signed certs
  - Problem: need a way to automatically distribute and vouch for these
  - SSH style "leap of faith" first time model
  - Transitive Trust Introduction model

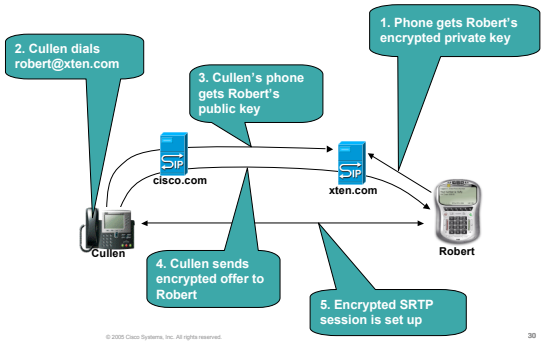
Don't Take ~~Candy~~ Calls From Strangers

Cisco.com

- When you don't know who you are talking to, you don't know if there is a man in the middle even when the voice verifies
- In some important calls, we don't recognize the voice of the person on the other end; and we need to phone people we have never communicated with before
- Encrypted media is far more valuable when coupled with strong cryptographic identity

Who Can Listen to Your Packets? Certificate Management Service for SIP

Cisco.com



Details

Cisco.com

- Fetching certificate done with SUB/NOT
- Allows invalidation of certificates with NOTIFY
- Would typically get certificate at time of subscribing to buddy presence not at time of call
- Phone can PUBLISH a credential (certificate + private key) to the certificate store
- Supports model where certificate store does not know private key as well as models where it does

Benefits

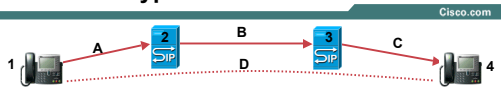
Cisco.com

- Absolutely no extra work on the part of the end user
- No extra cost to end user
  - Each enterprise or Service provider must have one web server style certificate for the domain
- Makes strong end to end encryption possible
- Avoids IPR entanglement
- Enterprises are comfortable running this type of service
  - It is very similar to presence server or https web server

MEDIA ENCRYPTION

Media Encryption

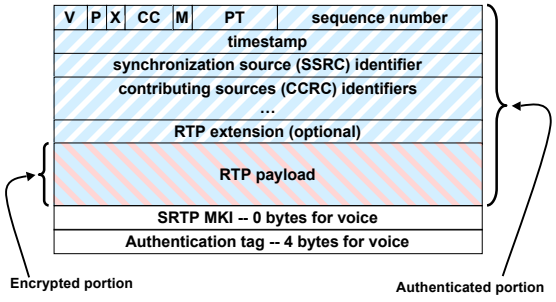
Cisco.com



- Use SRTP to protect RTP/RTCP media (audio, video)
  - Keying material is passed in SIP signaling
  - AES Counter Mode
    - counter derived from 16 bit RTP sequence number
    - 32 bit rollover counter provided in RTCP
  - Crypto generally: AES-CM, SHA1
- Protect Instant Messaging with S/MIME
  - Crypto generally: RSA, AES, SHA1

SRTP: voice encryption and authentication

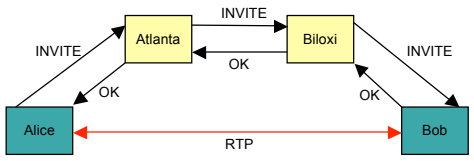
Cisco.com



MEDIA KEYING

Reminder: Basic Topology

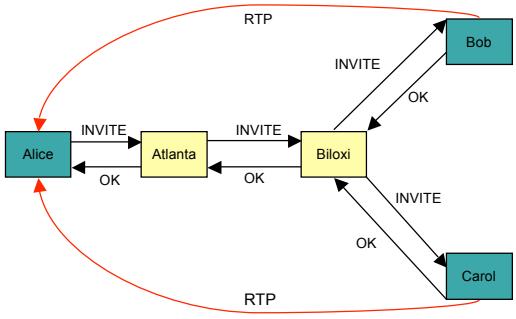
Cisco.com



- **SIP and RTP follow different paths**
  - **SIP: Signaling path**
  - **RTP: Media path**
- **Media path is often faster (fewer hops)**

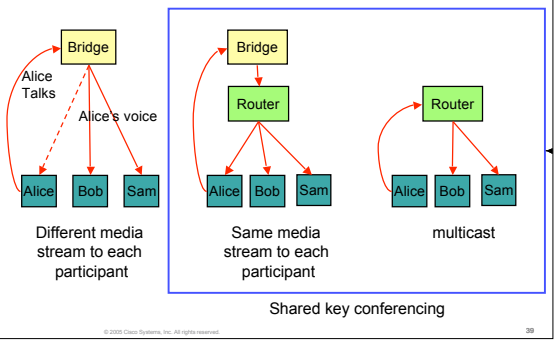
Forking

Cisco.com



Conferencing Architectures

Cisco.com



Media Keying: Standards Work in Progress

Cisco.com

	Sig. Conf.	Forking	Media before Answer	Shared-key conf.	PKI?	Rekey	Bid-down protection
MIKEY-PSK	No	No	Yes	Yes	No*	Yes	Yes
MIKEY-RSA	No	No	Yes	Yes	Yes	Yes	Yes
MIKEY-DH	No	No	No	No	Yes	Yes	Yes
MIKEY-DHHMAC	No	No	No	No	No*	Yes	Yes
MIKEY-RSA-R	No	Yes	No	Yes	Yes	Yes	Yes
SDES	Yes	Yes*	No	Yes	No	Yes*	No
SDES-EM	Yes	Yes*	Yes	Yes	No	Yes	No
EKT	Yes*	Yes*	Yes	Yes	No	Yes	*
SDP-DH	No	No	No	No	No	No	No
ZRTP	No	Yes	Yes	No	No	Yes	Yes
DTLS	No	Yes	Yes	No	No	Yes	Yes

HOT TOPICS

What Are SBC Good For?

Cisco.com

- **Making a UA do something that the UA should do but is not yet implemented**
  - **Converting SIP over UDP to SIP over TLS**
  - **Converting RTP to SRTP**

The Basic Facts About Firewall ALGs

Cisco.com

- **The Good**
  - It's nice that a firewall at the gate is only allowing in things that look like gifts
- **The Bad**
  - There is no way for the ALG to know what is OK in the context of this network
- **The Ugly**
  - ALGs break SIP and don't work with encrypted signaling

Do use Firewalls, but don't expect them to solve all problems

What Are ALGs Good For?

Cisco.com

- **Protecting your hosts from classes of traffic they should not receive**
  - Letting HTTP to Web Server is OK
  - Stopping outside packet to the data base server is Good

DENIAL OF SERVICE

DoS

Cisco.com

- DoS attacks are very hard to protect against in any system that allows data exchanges between parties with no previous relationship
- This is a key requirement of voice systems
- Goal is to keep the cost to the attacker as high as the cost to the target
- Many systems are vulnerable to TCP connection depletion
- Many load generators can trivially do tens of thousands of transactions per second, but signaling systems do more in the order of one thousand transactions per second. However bandwidth is symmetrical
- Critical not to allow devices in the core of the network to act as amplifiers (i.e. to receive one message and send many)
  - This is the key problem holding up much of the Push To Talk (PTT) work at IETF

Solutions to DoS

Cisco.com

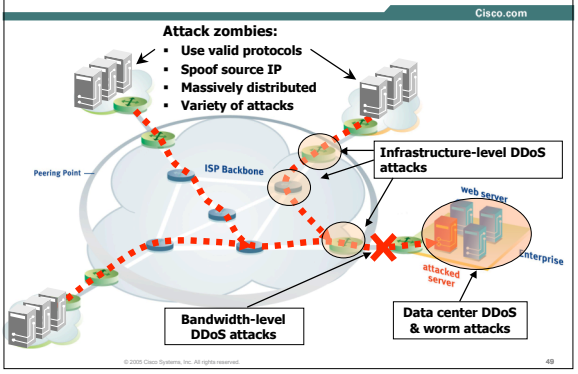
- Track the packets back towards the source
- Do one of the following on the source
  - Rate limit the source
  - Disconnect the source
  - Beat the source with a very large stick
- Important to be able to identify and find the source

DDoS

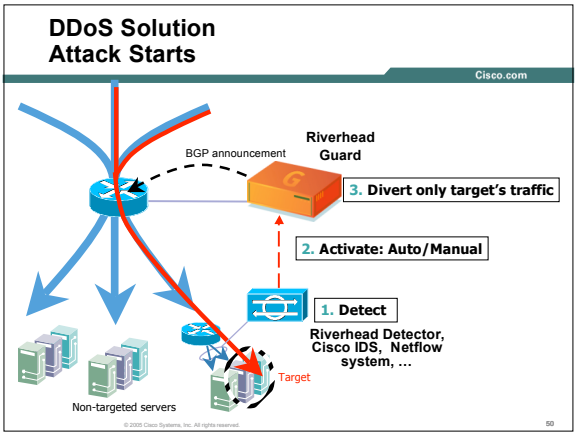
Cisco.com

- Harder than DoS because it obfuscates the source and makes many apparent sources
- Solutions mostly involve making sure that if a SIP device forwards a packet on behalf of some sender, it records the original sender in the forwarded packet. Allows the real source to be identified
- Solutions are similar to DoS but harder to implement automatically

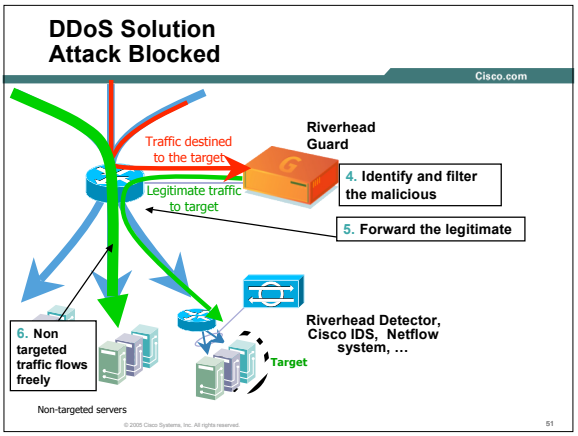
DDoS Attacks



DDoS Solution Attack Starts



DDoS Solution Attack Blocked



DoS & DDoS Summary

Cisco.com

- Know who the packets are coming from
- Ensure Return Routable on packets
- Rate limit as close to source as possible
- Use large stick

RISK & COST

Comparison to PSTN

Cisco.com

- In many ways PSTN is good with respect to toll fraud
  - Still a very large amount of toll fraud on PSTN
- No voice crypto
  - Person in wiring closet can listen to calls
  - Anyone willing to poke around can listen to calls
- Caller ID is bogus (see *38)
  - Anyone can produce fake caller id for a few hundred dollars
- Is the security of the PSTN good enough?
  - Will you give you credit card number over the telephone?
  - Discuss a merger?

Comparison: Email, PSTN, & VoIP

Cisco.com

	PSTN	EMAIL	VoIP
Hijack protection	OK	good (relies on DNS)	excellent
Off path snooping	good	ok	good
On path snooping	very bad	bad	good if using TLS & SRTP
Fake identity	bad	very very bad	good with Identity (bad otherwise)
Encryption	no	not used	some use and very good with TLS & SRTP

STATE of the INDUSTRY

Ongoing Work at IETF

Cisco.com

- SRTP Keying
- Voice/Video/IM SPAM prevention
- Retargeting traceability (History)
- Certificate management
- Models for enrollment
- BEHAVE NAT design guidelines
- Delegation of authorization to 3rd parties
- Passing credentials to middle boxes such as firewalls
- ….. and many more :-)

VoIP Security Checklist

Cisco.com

- How does the system authenticate users?
  - Digest and Mutual TLS are good answers
- How does the system protect privacy of signaling?
  - TLS is a good answer
- How does the system do media privacy?
  - SRTP and S/MIME are good answers
- Do you know who you are talking to?
  - Identity is a good answer
- Can devices easily be enrolled in the system?

Summary

Cisco.com

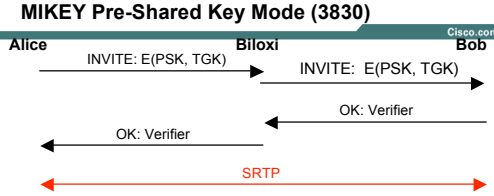
- Voice security is complex but necessary and feasible
  - SIP networks are complex. SIP is a multi-domain, multi-party, peer-to-peer rendezvous system
  - The internet community has never secured a protocol this broad before
- The tools exist to secure this system. SIP and RTP address threats using:
  - Digest
  - TLS
  - S/MIME
  - SRTP
  - STUN

CISCO SYSTEMS

EMPOWERING THE INTERNET GENERATION

MIKEY Pre-Shared Key Mode (3830)

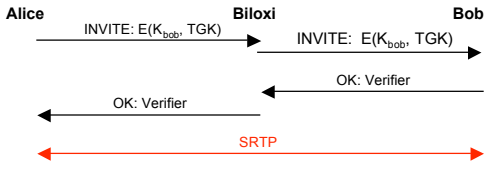
Cisco.com



Requires signalling confidentiality	No
Forking	No
Media before SDP answer	Yes
Shared-key conferencing	Yes
Requires PKI	No (but pre shared key)
Rekeying	Yes
Downgrade attack protection	Yes

MIKEY Public Key Mode (3830)

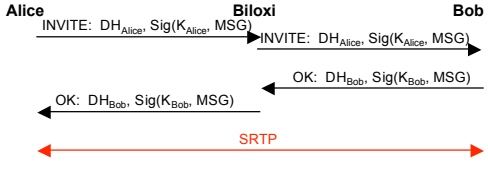
Cisco.com



Requires signalling confidentiality	No
Forking	No
Media before SDP answer	Yes
Shared-key conferencing	Yes
Requires PKI	Yes
Rekeying	Yes
Downgrade attack protection	Yes

MIKEY Diffie-Hellman Mode (3830)

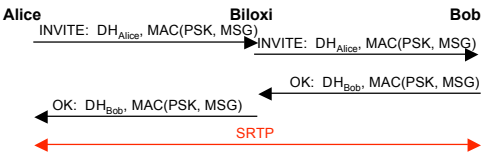
Cisco.com



Requires signalling confidentiality	No
Forking	Yes
Media before SDP answer	No
Shared-key conferencing	No
Requires PKI	Yes
Rekeying	Yes
Downgrade attack protection	Yes

MIKEY Diffie-Hellman HMAC Mode (draft-ietf-msec-mikey-dhhmac-11)

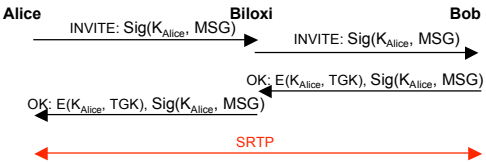
Cisco.com



Requires signalling confidentiality	No
Forking	Yes
Media before SDP answer	No
Shared-key conferencing	No
Requires PKI	No (pre-shared key)
Rekeying	Yes
Downgrade attack protection	Yes

MIKEY RSA-R Mode (draft-ietf-msec-mikey-rsa-r-02)

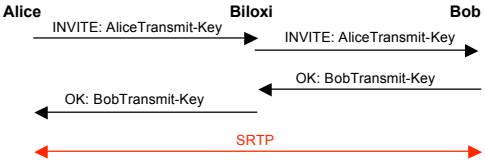
Cisco.com



Requires signalling confidentiality	No
Forking	Yes
Media before SDP answer	No
Shared-key conferencing	Yes
Requires PKI	Yes
Rekeying	Yes
Downgrade attack protection	Yes

SDESCRIPTIONS (draft-ietf-mmusic-sdescriptions-12)

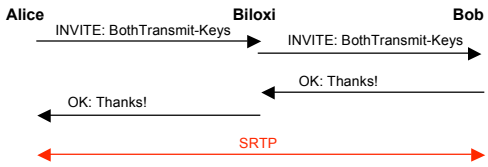
Cisco.com



Requires signalling confidentiality	Yes
Forking	Yes (insecure)
Media before SDP answer	No
Shared-key conferencing	Yes
Requires PKI	No
Rekeying	Yes (New Offer)
Downgrade attack protection	No

SDES Early Media Mode (draft-wing-mmusic-sdes-early-media-00)

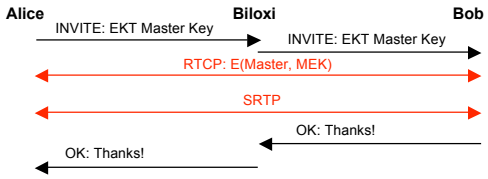
Cisco.com



Requires signalling confidentiality	Yes
Forking	Yes (insecure)
Media before SDP answer	Yes
Shared-key conferencing	Yes
Requires PKI	No
Rekeying	Yes (New Offer)
Downgrade attack protection	No

Encrypted Key Transport w/ SDES (draft-mcgrew-srtp-ekt-00)

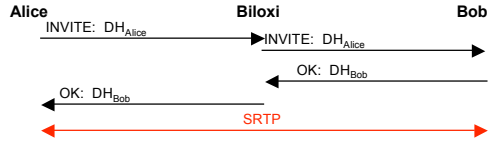
Cisco.com



Requires signalling confidentiality	In SDES mode
Forking	Yes (insecure)
Media before SDP answer	Yes
Shared-key conferencing	Yes
Requires PKI	No
Rekeying	Yes
Downgrade attack protection	Depends on base handshake

SDP DH Mode (draft-baugher-mmusic-sdp-00)

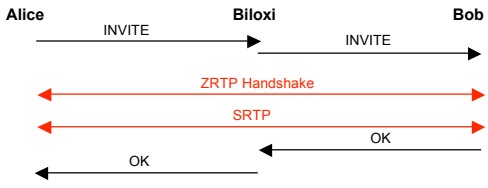
Cisco.com



Requires signalling confidentiality	No
Forking	No
Media before SDP answer	No
Shared-key conferencing	No
Requires PKI	No
Rekeying	No
Downgrade attack protection	No

ZRTP (draft-zimmermann-avt-zrtp-01)

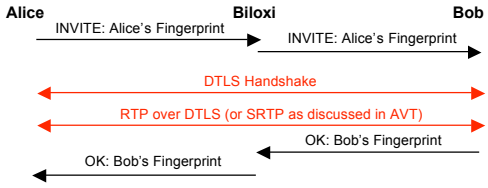
Cisco.com



Requires signalling confidentiality	No
Forking	Yes
Media before SDP answer	Yes
Shared-key conferencing	No
Requires PKI	No
Rekeying	Yes
Downgrade attack protection	Yes

DTLS/RTP (draft-tschofenig-avt-rtp-dtls-00, etc.)

Cisco.com



Requires signalling confidentiality	No
Forking	Yes
Media before SDP answer	Yes
Shared-key conferencing	No
Requires PKI	No
Rekeying	Yes
Downgrade attack protection	Yes