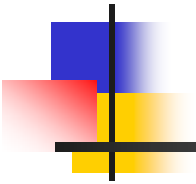


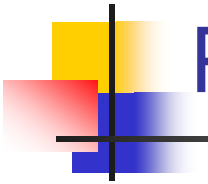
NAT Traversal for VoIP

Ai-Chun Pang

Graduate Institute of Networking and Multimedia

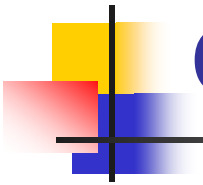
Dept. of Comp. Sci. and Info. Engr.

National Taiwan University



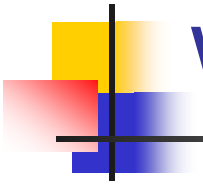
References

- “SIP, NAT and Firewalls”, Fredrik Thernelius
- Baruch Sterman and David Schwartz, “NAT Traversal in SIP”, Deltathree
- “STUN – Simple Traversal of UDP Through Network Address Translators”, RFC 3489, IETF
- “An Extension to the SIP for Symmetric Response Routing”, RFC 3581, IETF
- “TURN – Traversal Using Relay NAT”, Internet Draft, IETF



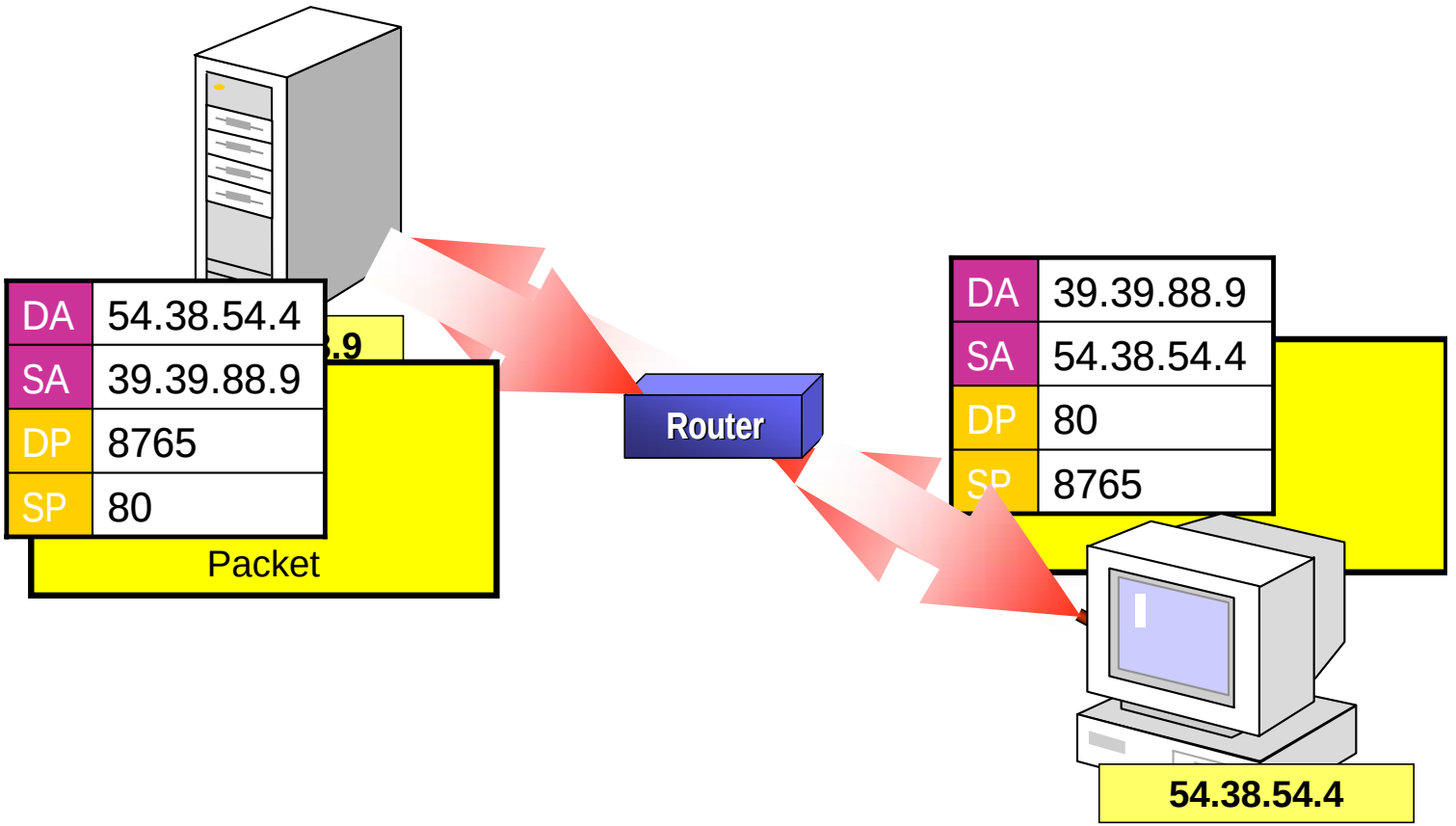
Outline

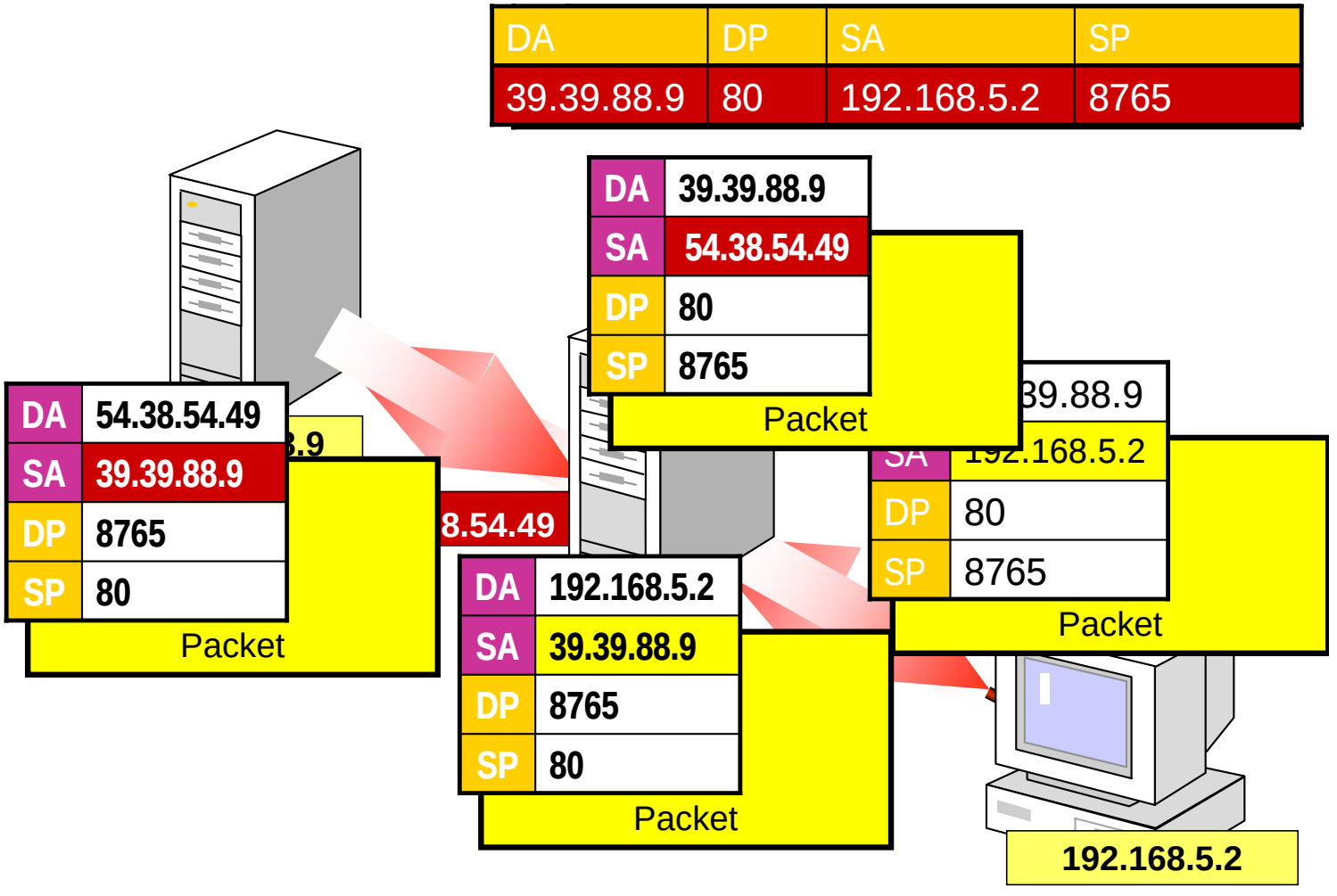
- Introduction
- Problems of NAT Traversal for VoIP
- Possible Solutions for VoIP over NAT

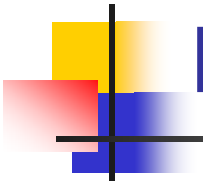


What is NAT?

- NAT - Network Address Translation
- Converts Network Address (and Port) between private and public realm
- Works on IP layer
- Transparent to Upper-layer Applications


DA
54.38.54.4
SA
39.39.88.9
DP
8765
SP
80
Packet
Router
DA
39.39.88.9
SA
54.38.54.4
DP
80
SP
8765
54.38.54.4

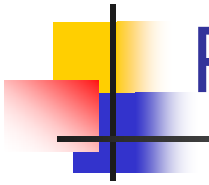

DA
DP
SA
SP
39.39.88.9
80
192.168.5.2
8765
DA
39.39.88.9
SA
54.38.54.49
DP
80
SP
8765
Packet
DA
54.38.54.49
SA
39.39.88.9
DP
8765
SP
80
Packet
DA
192.168.5.2
SA
39.39.88.9
DP
8765
SP
80
Packet
DP
80
SP
8765
Packet
192.168.5.2



Flavors of NAT [1/3]

Static NAT

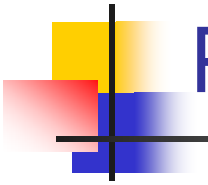
- Requires the same number of globally IP addresses as that of hosts in the private environment
- Maps between internal IP addresses and external addresses is set manually
  - This mapping intends to stay for a long period of time



Flavors of NAT [2/3]

Dynamic NAT

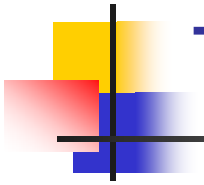
- Collect the public IP addresses into an IP address pool
- A host connecting to the outside network is allocated an external IP address from the address pool managed by NAT



Flavors of NAT [3/3]

NAPT (Network Address and Port Translation)

- A special case of Dynamic NAT
  - Use port numbers as the basis for the address translation
- Most commonly used

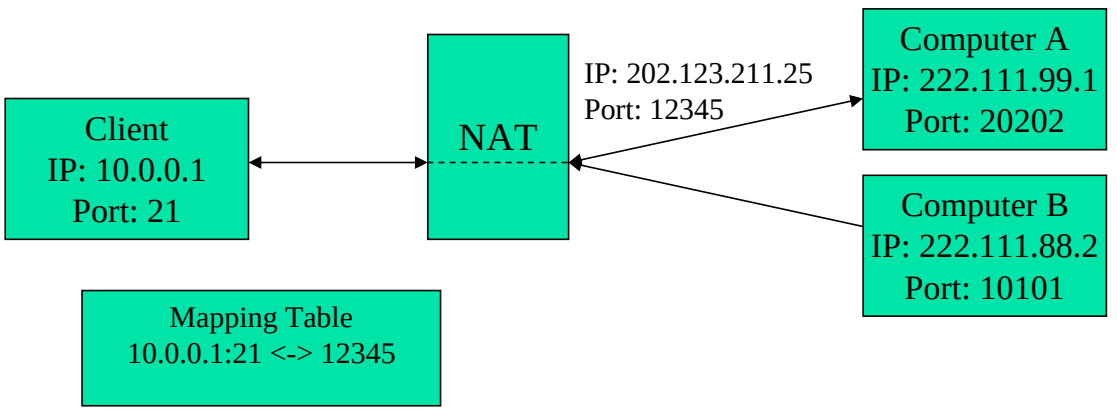


Types of NAT

- Full Cone
- Restricted Cone
- Port Restricted Cone
- Symmetric

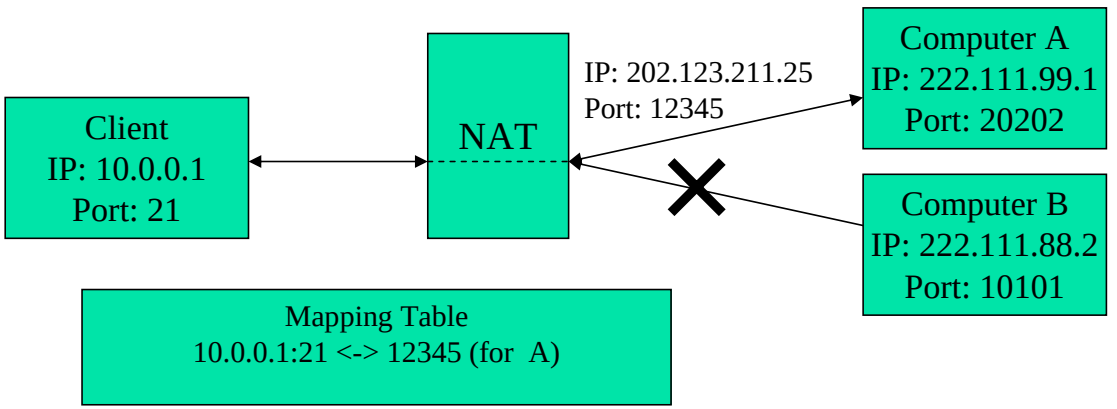
Full Cone NAT

- Client sends a packet to public address A.
- NAT allocates a public port (12345) for private port (21) on the client.
- Any incoming packet (from A or B) to public port (12345) will dispatch to private port (21) on the client.



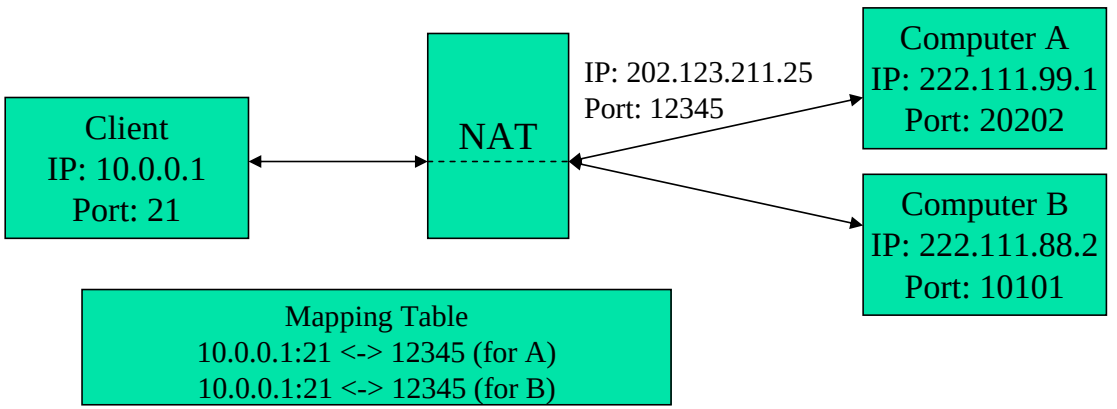
Restricted Cone NAT [1/2]

- Client sends a packet to public address A.
- NAT allocate a public port (12345) for private port (21) on the client.
- Only incoming packet from A to public port (12345) will dispatch to private port (21) on the client.



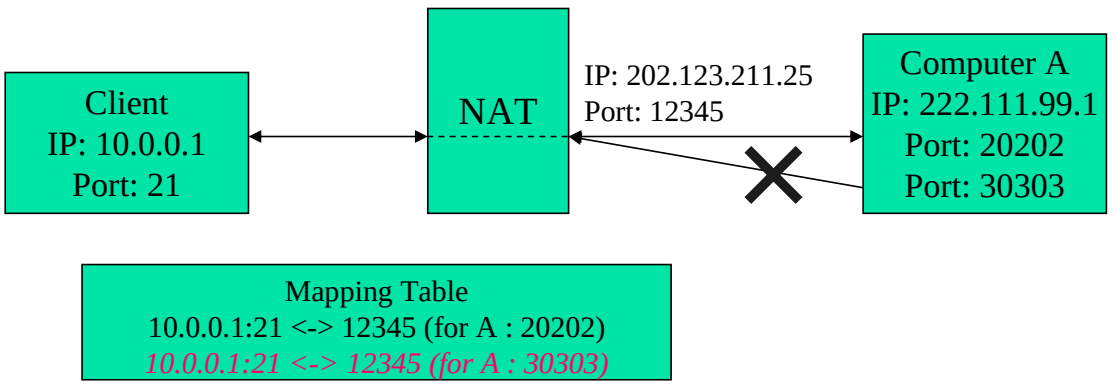
Restricted Cone NAT [2/2]

- Client sends another packet to public address B.
- NAT will reuse allocated public port (12345) for private port (21) on the client.
- Incoming packet from B to public port (12345) will now dispatch to private port (21) on the client.



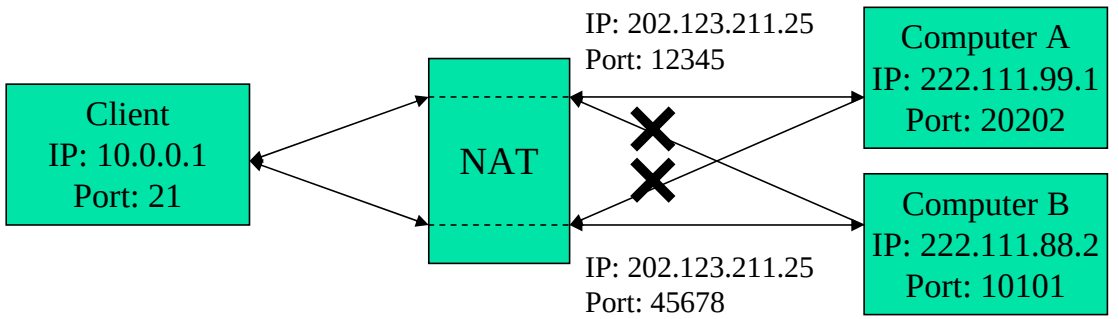
Port Restricted Cone NAT

- Client sends a packet to public address A at port 20202.
- NAT will allocate a public port (12345) for private port (21) on the client.
- Only incoming packet from address A and port 20202 to public port (12345) will dispatch to private port (21) on the client.

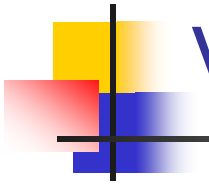


Symmetric NAT

- NAT allocates a public port each time the client sends a packet to different public address and port
- Only incoming packet from the original mapped public address and port will dispatch to private port on client

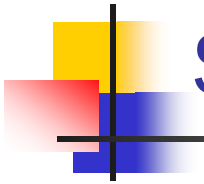


Mapping Table
10.0.0.1:21 <-> 12345 (for A : 20202)
10.0.0.1:21 <-> 45678 (for B : 10101)



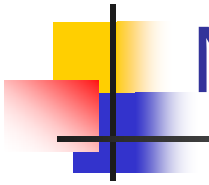
VoIP Protocol and NAT

- NAT converts IP addresses on IP layer
- Problem 1:
  - SIP, H.323, Megaco and MGCP are application layer protocol but contain IP address/port info in messages, which is not translated by NAT
- Problem 2:
  - Private client must send an outgoing packet first (to create a mapping on NAT) to receive incoming packets



Solving NAT Traversal Problems

- Objectives
  - To discover the mapped public IP & port for a private IP & port
  - To use the mapped public IP & port in application layer message
  - To keep this mapping valid
- Issues
  - NAT will **automatically** allocate a public port for a private address & port if needed.
  - NAT will release the mapping if the public port is “idle”
    - No TCP connection on the port
    - No UDP traffic on the port for a period
  - Keep a TCP connection to destination
  - Send UDP packets to destination every specified interval

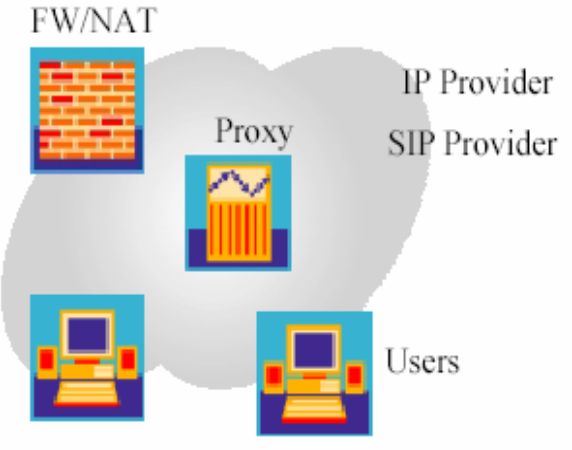


NAT Solutions

- IPv6 (Internet Protocol Version 6)
- UPnP (Universal Plug-and-Play)
  - UPnP Forum - http://www.upnp.org/
- Proprietary protocol by NAT/Firewall
  - SIP ALG (Application Level Gateway)
- SIP extensions for NAT traversal
  - RFC 3581
  - Works for SIP only, can not help RTP to pass through NAT
- STUN (Simple Traversal of UDP Through Network Address Translators)
  - RFC 3489
  - Works except for symmetric NAT
- TURN (Traversal Using Relay NAT)
  - draft-rosenberg-midcom-turn-04
  - for symmetric NAT

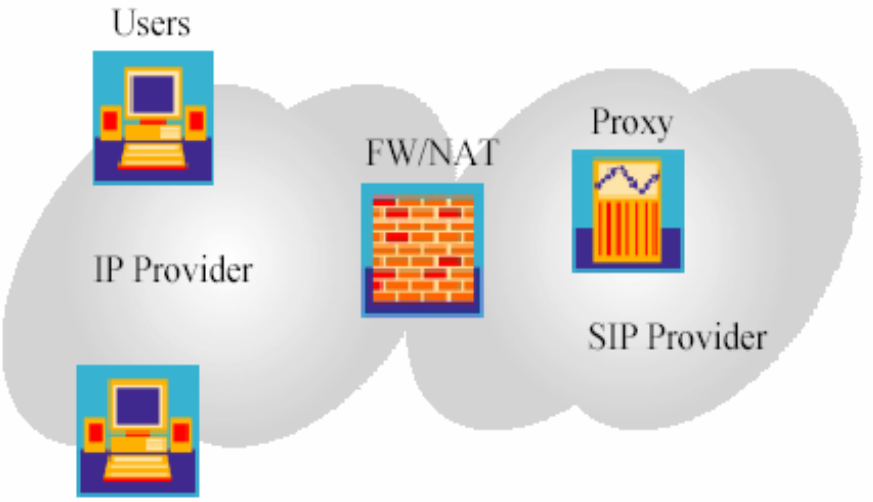
Two Distinct Cases – NAT Deployment [1/2]

Case I : SIP Provider is the IP Network Provider



Two Distinct Cases – NAT Deployment [2/2]

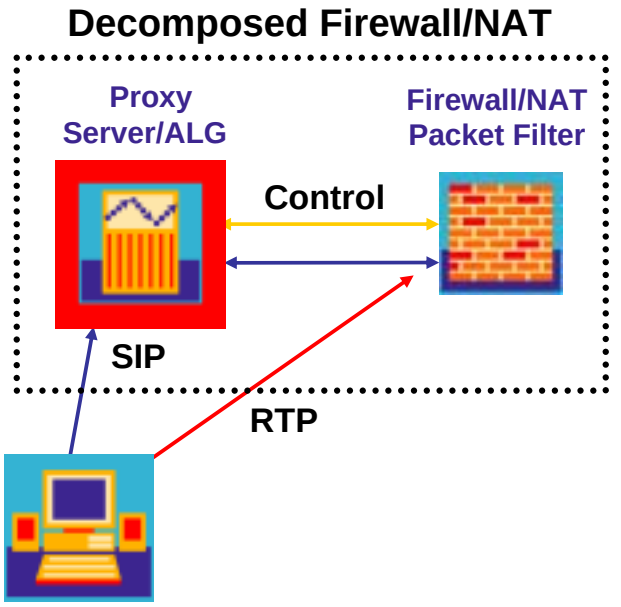
Case II : SIP Provider is **NOT** IP Network Provider



Solution for Case I – ALG [1/2]

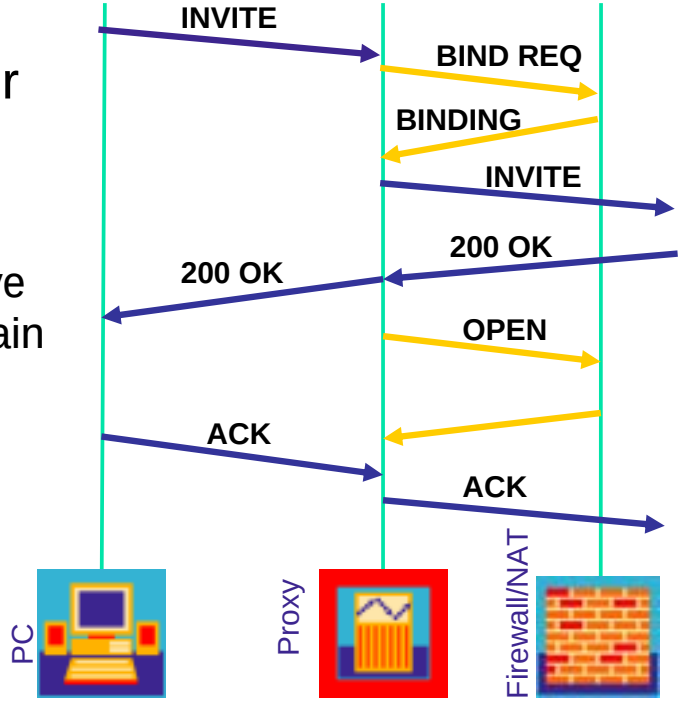
Separate Application Layer NAT from IP Layer NAT

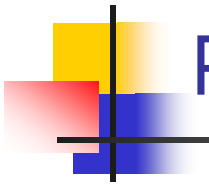
- **Like MEGACO Decomposition**
  - **MG = Packet Filter**
  - **MGC = Control Proxy**
- **Advantages**
  - **Better scaling**
  - **Load balancing**
  - **Low cost**



Solution for Case I – ALG [2/2]

- A control Protocol between application-layer NATs and IP-layer NATs
- Main Requirements
  - **Binding Request**: To give a private address and obtain a public address
  - **Binding Release**
  - **Open Hole** (firewall)
  - **Close Hole** (firewall)





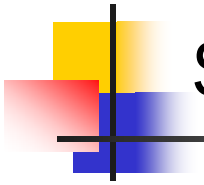
Proposed Solution for Case II

Much harder problem

- No way to control firewall or NAT
- Cascading NATs
- Variable firewall NAT behaviors

Proposed Solution

- Make SIP "NAT-Friendly"
  - Minor extensions
  - Address the issues for SIP only, not RTP
  - Accepted by IETF (RFC 3581)
- Develop a protocol for traversal of UDP through NAT
  - Work for RTP
  - Also support other applications



SIP Extension to NAT Friendly

Client Behavior

- Include an “**rport**” parameter in the Via header
  - This parameter MUST have no value
  - It serves as a flag
- The client SHOULD retransmit its INVITE every 20 seconds
  - Due to UDP NAT binding period and to keep the binding fresh

SIP Extension to NAT Friendly [2/2]

Server Behavior

- Examines the Via header field value of the request
  - If it contains an "**rport**" parameter,
    - A "**received**" parameter
    - An "**rport**" parameter
- The response MUST be sent to the IP address listed in the "received" parameter, and the port in the "rport" parameter.

Example [1/2]

Client A: 10.1.1.1
Proxy B: 68.44.10.3
NAT C: 68.44.20.1

- A issues request
  INVITE sip:user@domain SIP/2.0
  Via: SIP/2.0/UDP 10.1.1.1:4540;**rport**

- A→C (mapping port 9988)→B
  INVITE sip:user@domain SIP/2.0
  Via: SIP/2.0/UDP proxy.domain.com
  Via: SIP/2.0/UDP 10.1.1.1:4540;
  received=68.44.20.1;rport=9988;

Example [2/2]

- Server B receives the response
  SIP/2.0 200 OK
  Via: SIP/2.0/UDP proxy.domain.com
  Via: SIP/2.0/UDP
  10.1.1.1:4540;**received=68.44.20.1**;**rport=9988**;

- B (68.44.10.3:5060) → C (68.44.20.1:9988) → A
  SIP/2.0 200 OK
  Via: SIP/2.0/UDP
  10.1.1.1:4540;**received=68.44.20.1**;**rport=9988**;

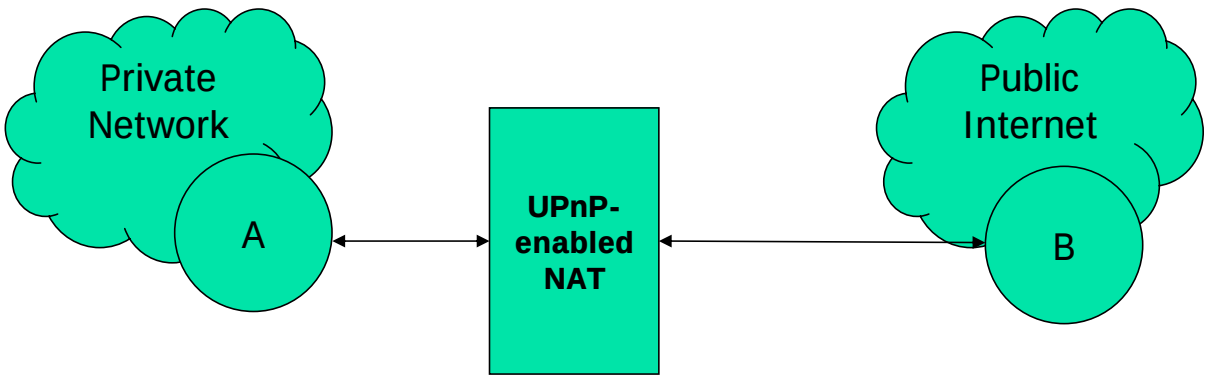
UPnP [1/2]

http://www.upnp.org/

- Universal Plug and Play
- It is being pushed by Microsoft
  - Windows® Messenger
- A UPnP-aware client can ask the UPnP-enabled NAT how it would map a particular IP:port through UPnP
- It will not work in the case of cascading NATs

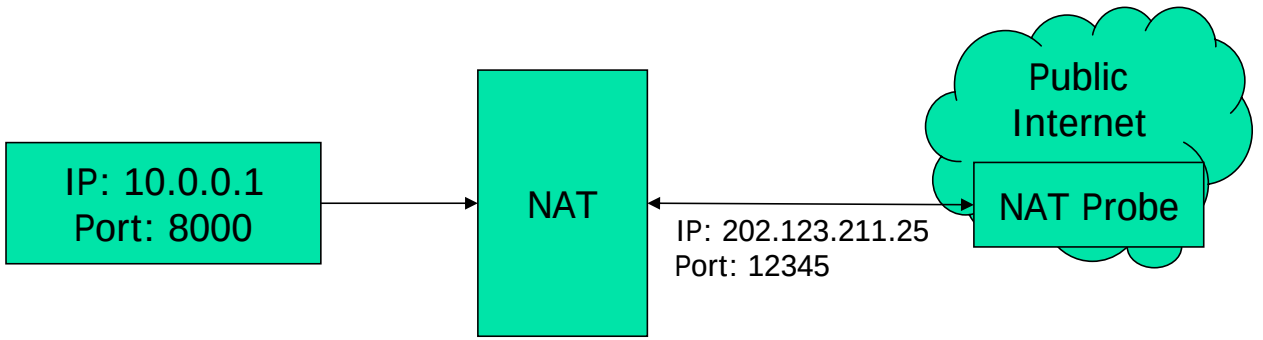
UPnP [2/2]

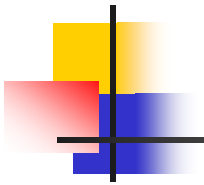
- A: Private Network
  - UPnP-aware Internet gateway device
  - The UPnP-enabled NAT allows “A” to be aware of its external IP
- B: Public Internet
  - “B” and “A” can communicate with each other



External Query

- A server sits listening for packets (**NAT probe**)
- When receiving a packet, it returns a message from the same port to the source containing the IP:port that it sees



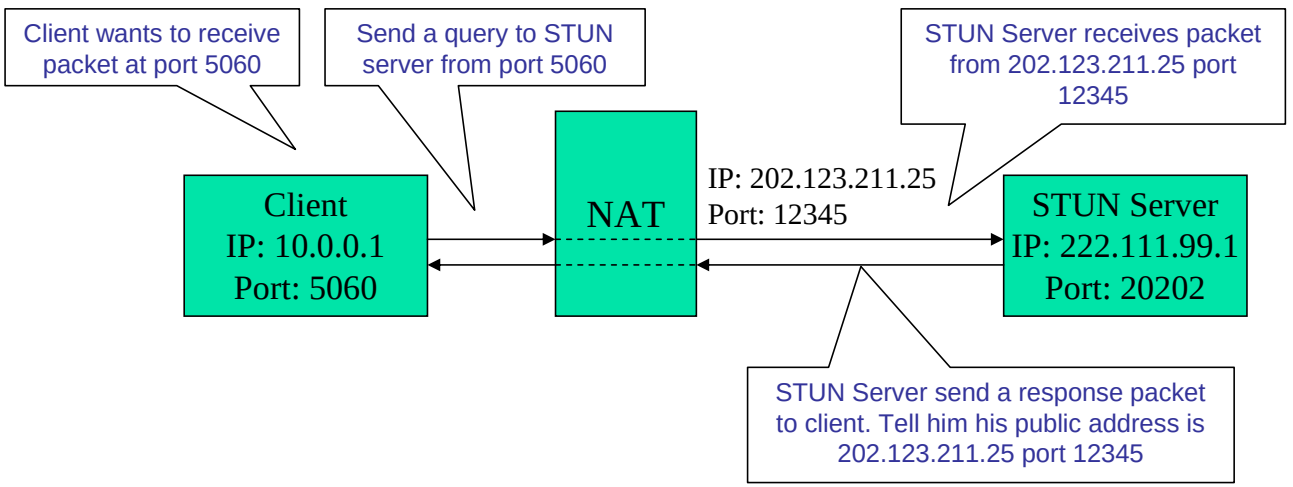


STUN

- Simple Traversal of UDP Through NAT
- RFC 3489
- In Working Group IETF MIDCOM Group
- Simple Protocol
- Works with existing NATs
- Main features
  - Allow Client to Discover Presence of NAT
  - Works in Multi-NAT Environments
  - Allow Client to Discover the Type of NAT
  - Allows Client to Discover the Binding Lifetimes
  - Stateless Servers

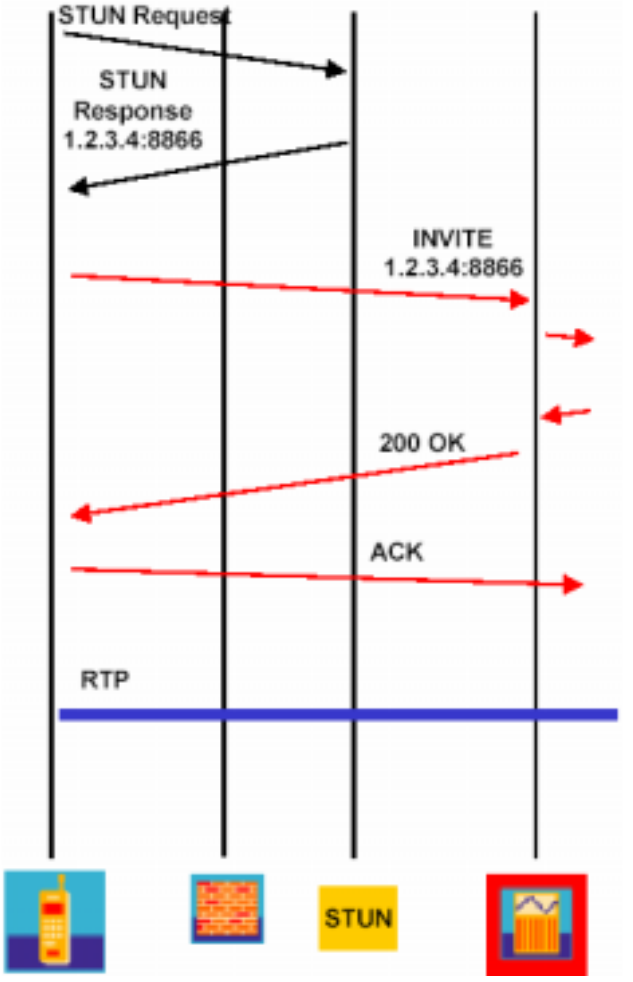
STUN Server

- Allow client to discover if it is behind a NAT, what type of NAT it is, and the public address & port NAT will use.
- A simple protocol, easy to implement, little load



Binding Acquisition

- STUN Server can be ANYWHERE on Public Internet
- Call Flow Proceeds Normally

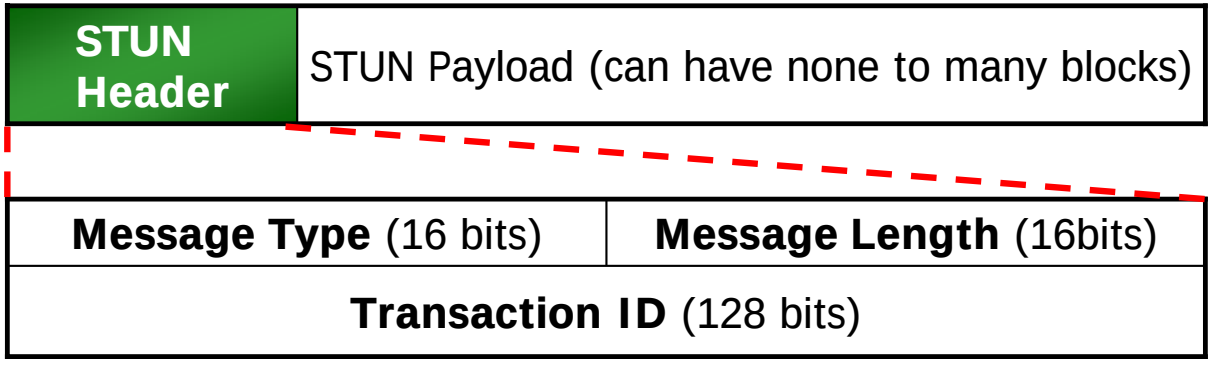


STUN Message [1/3]

- TLV (type-length-value)
- Start with a STUN header, followed by a STUN payload (a series of STUN attributes depending on the message type)
- Format

STUN Header	STUN Payload (can have none to many blocks)

STUN Message [2/3]

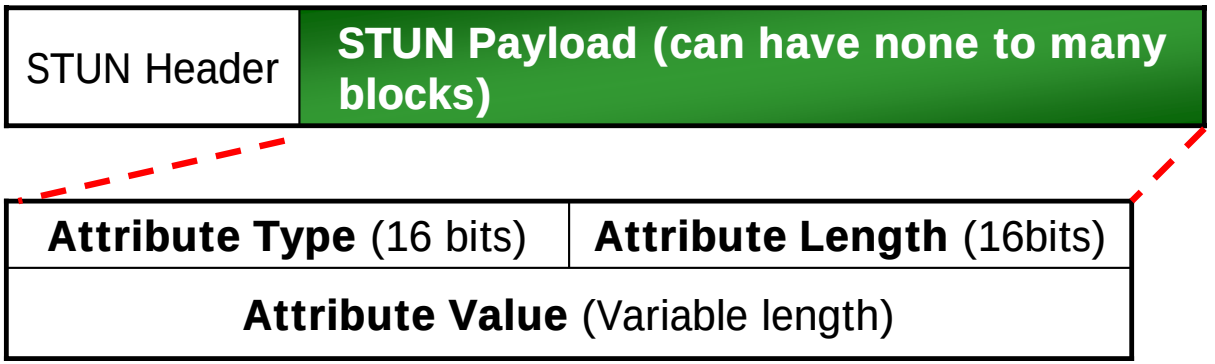


Message Types

0x0001: Binding Request
0x0101: Binding Response
0x0111: Binding Error Response

0x0002: Shared Secret Request
0x0102: Shared Secret Response
0x0112: Shared Secret Error Response

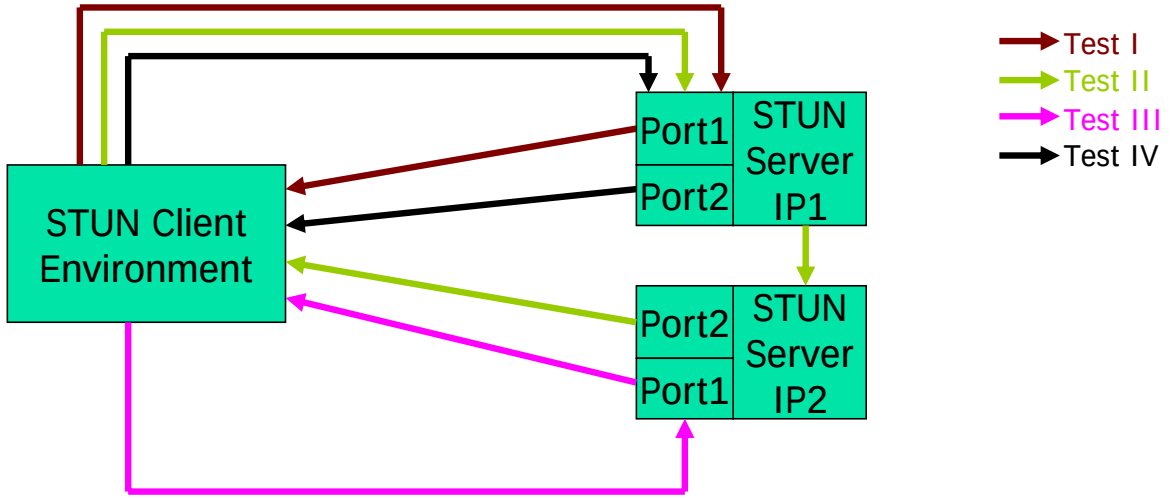
STUN Message [3/3]



Attribute Types

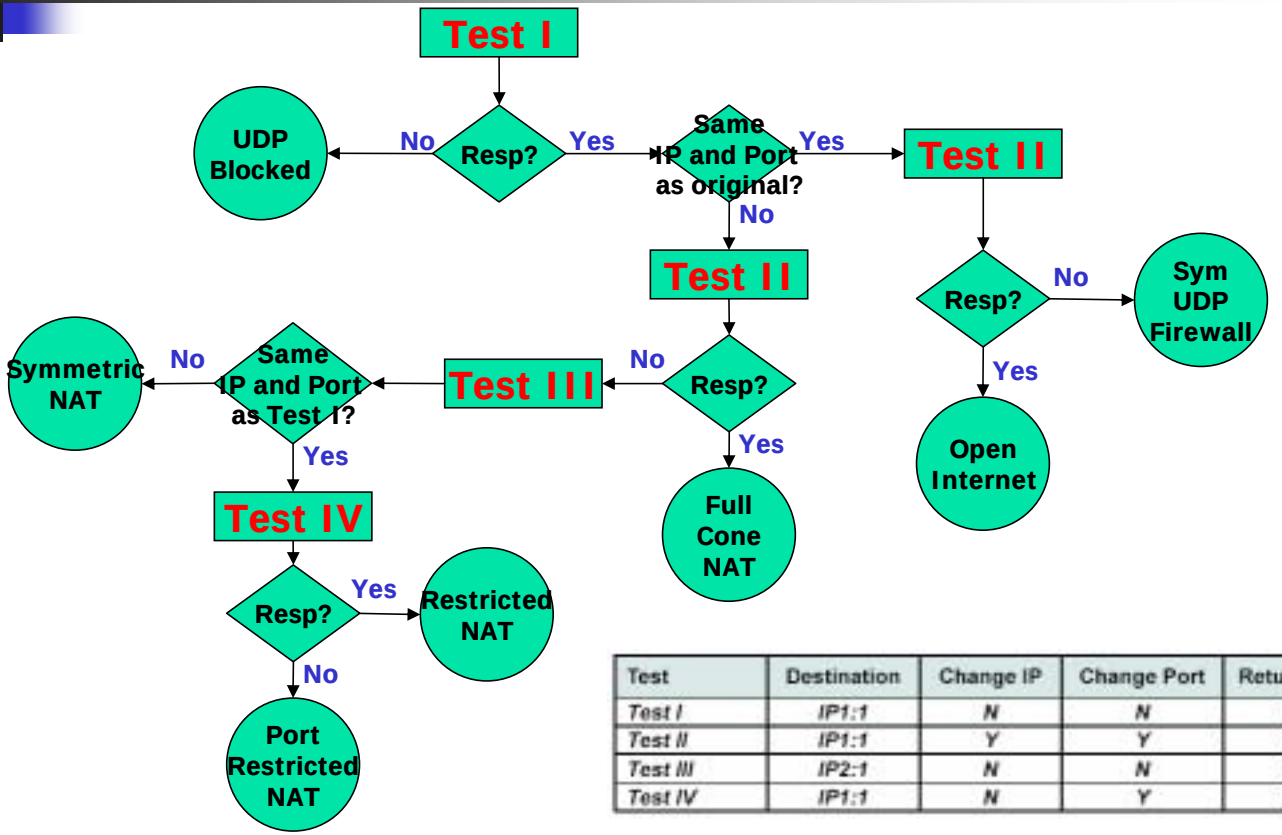
0x0001: MAPPED-ADDRESS
0x0002: RESPONSE-ADDRESS
0x0003: CHANGE-REQUEST
0x0004: SOURCE-ADDRESS
0x0005: CHANGED-ADDRESS
0x0006: USERNAME
0x0007: PASSWORD
0x0008: MESSAGE-INTEGRITY
0x0009: ERROR-CODE
0x000a: UNKNOWN-ATTRIBUTES
0x000b: REFLECTED-FROM

Automatic Detection of NAT Environment [1/2]



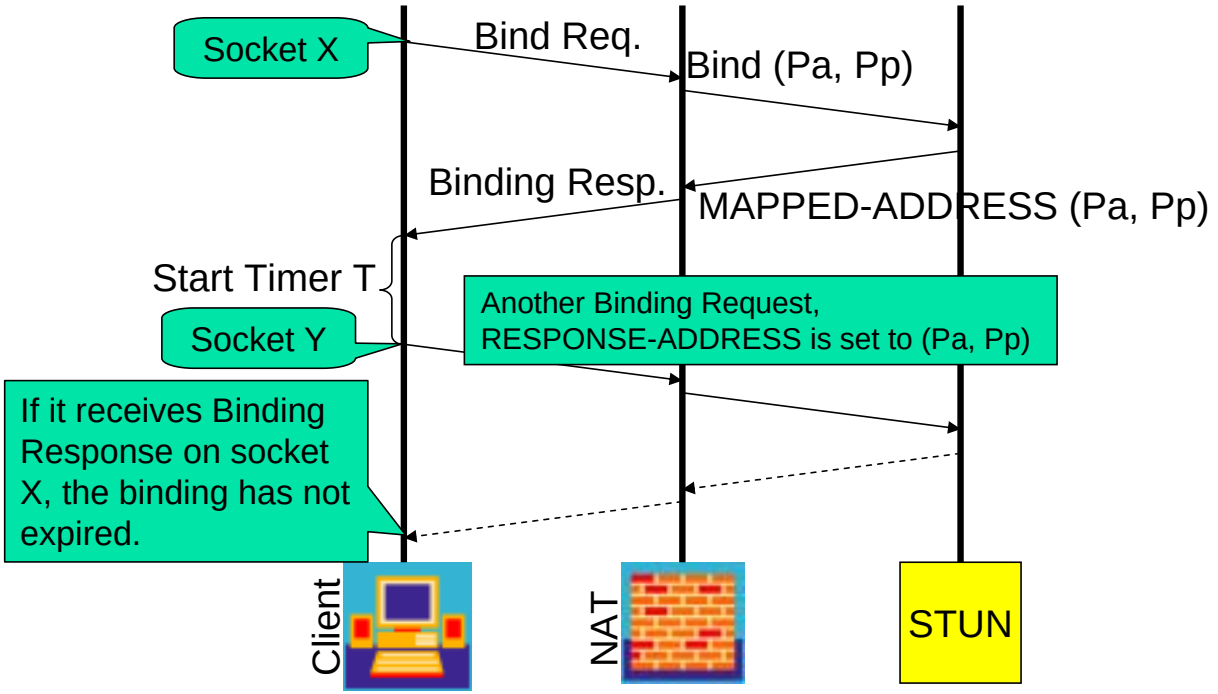
Test	Destination	Change IP	Change Port	Return IP:port
Test I	*IP1:1*	*N*	*N*	*IP1:1*
Test II	*IP1:1*	*Y*	*Y*	*IP2:2*
Test III	*IP2:1*	*N*	*N*	*IP2:1*
Test IV	*IP1:1*	*N*	*Y*	*IP1:2*

Automatic Detection of NAT Environment [2/2]

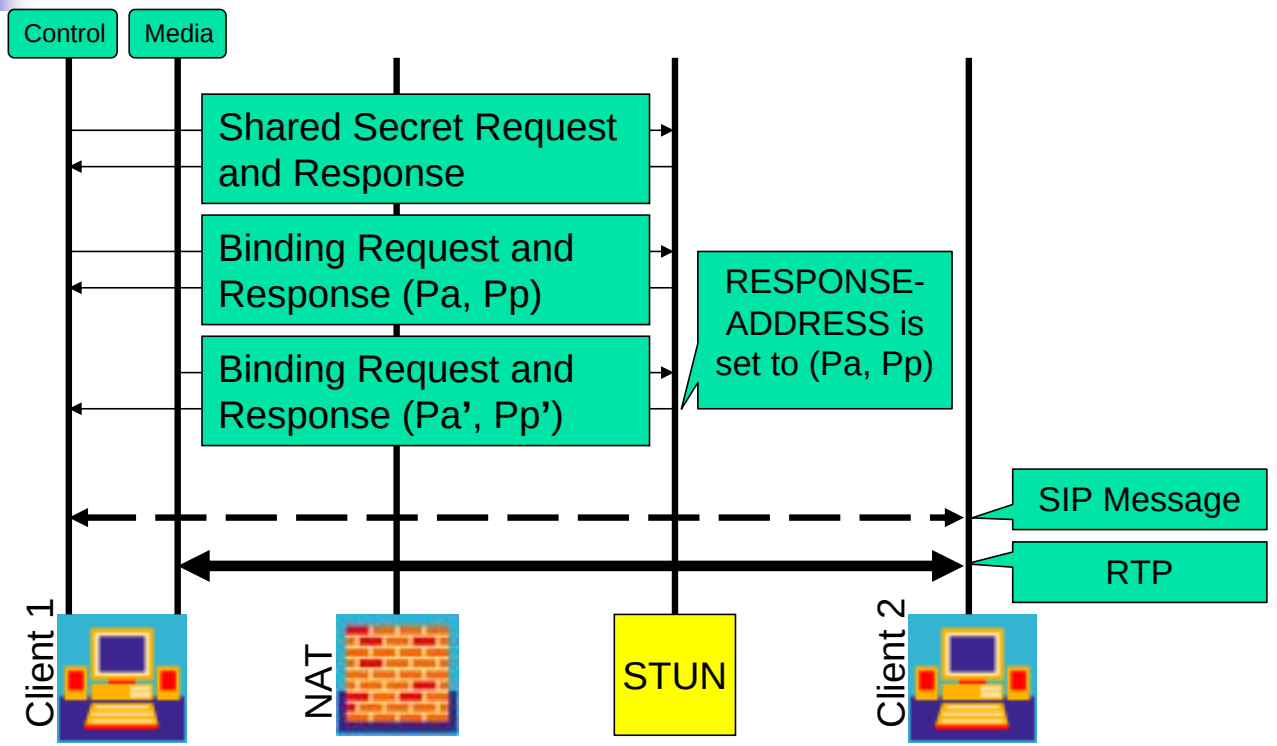


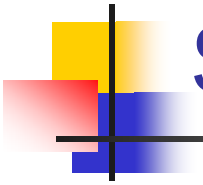
Test	Destination	Change IP	Change Port	Return IP:port
Test I	*IP1:1*	*N*	*N*	*IP1:1*
Test II	*IP1:1*	*Y*	*Y*	*IP2:2*
Test III	*IP2:1*	*N*	*N*	*IP2:1*
Test IV	*IP1:1*	*N*	*Y*	*IP1:2*

Binding Lifetime Determination



Binding Acquisition Procedure



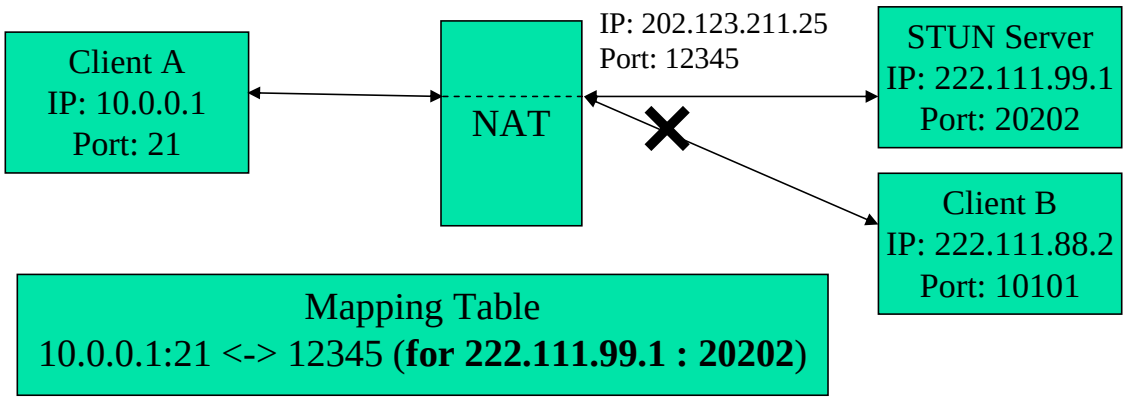


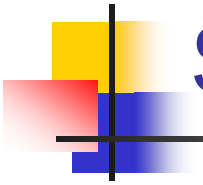
STUN - Pros and Cons

- Benefits
  - No changes required in NAT
  - No changes required in Proxy
  - Works through most residential NAT
- Drawbacks
  - Doesn’t allow VoIP to work through Symmetric NAT
  - RTCP may not work

Is STUN suitable for Symmetric NAT

- Absolutely not

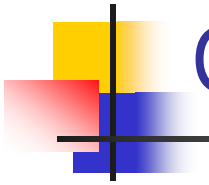




Solutions for Symmetric NATs

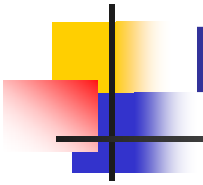
- Connection Oriented Media
- RTP-Relay

Connection Oriented Media



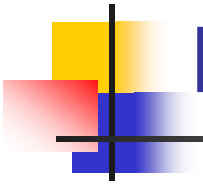
- The endpoint outside the NAT must wait until it receives a packet from the client before it can know where to reply
- Add a line to the SDP message (coming from the client behind the NAT)

  a=direction:active
- The initiating client will “actively” set up the IP:port to which the endpoint should return RTP
  - The IP:port found in the SDP message should be ignored



Problem?

1) If the endpoint does not support the **a=direction:active** tag
2) If both endpoints are behind Symmetric NATs

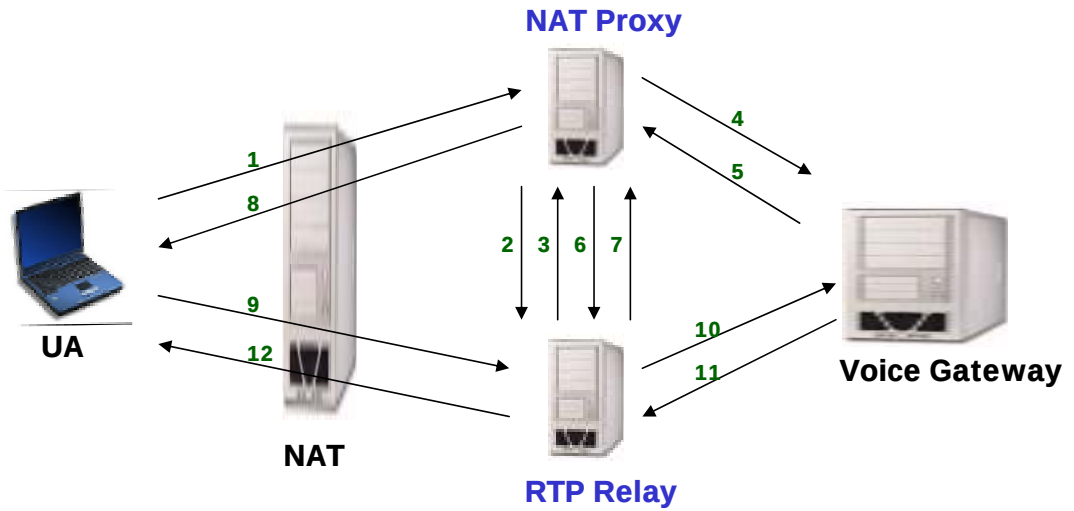


RTP-Relay

- For either of the cases considered in the previous slide, one solution is to have an RTP Relay in the middle of the RTP flow between endpoints.
- The RTP Relay acts as the second endpoint to each of the actual endpoints that are attempting to communicate with each other.

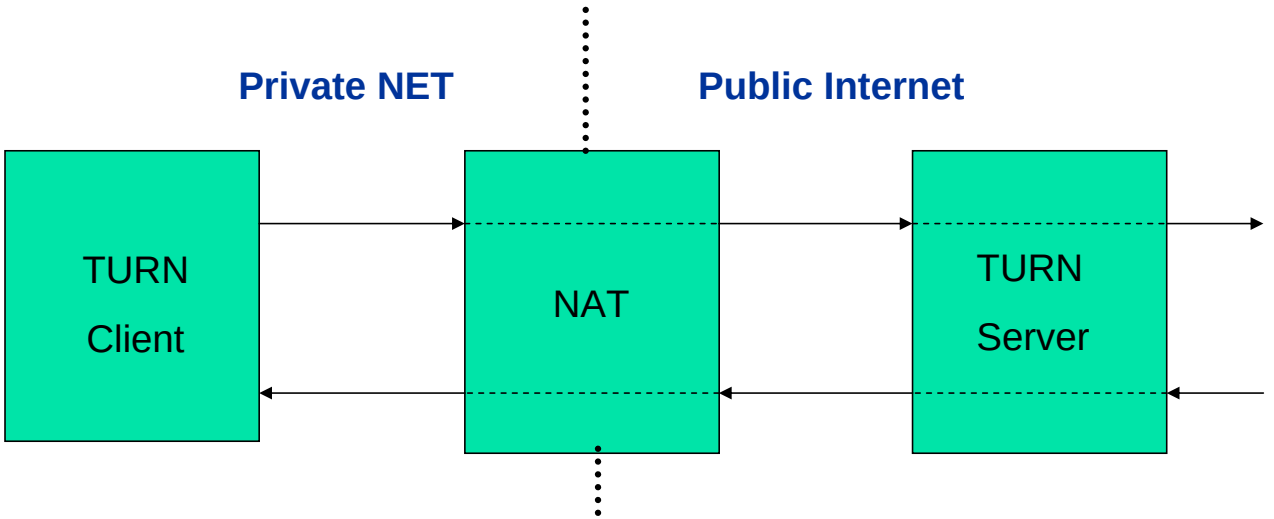
Example

The following is a typical call flow that might be instantiated between a User Agent behind a symmetric NAT and a voice gateway on the open Internet.

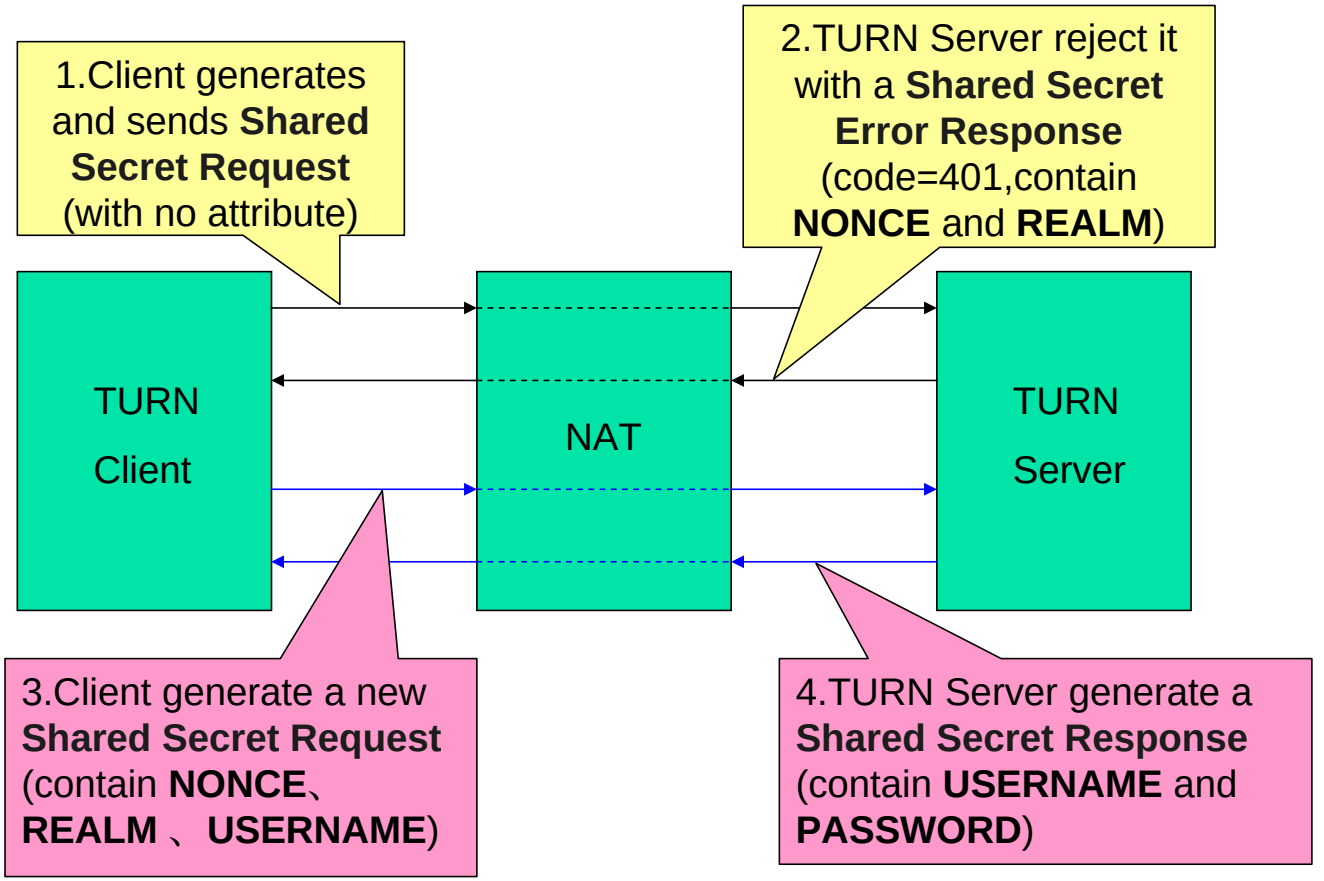


TURN

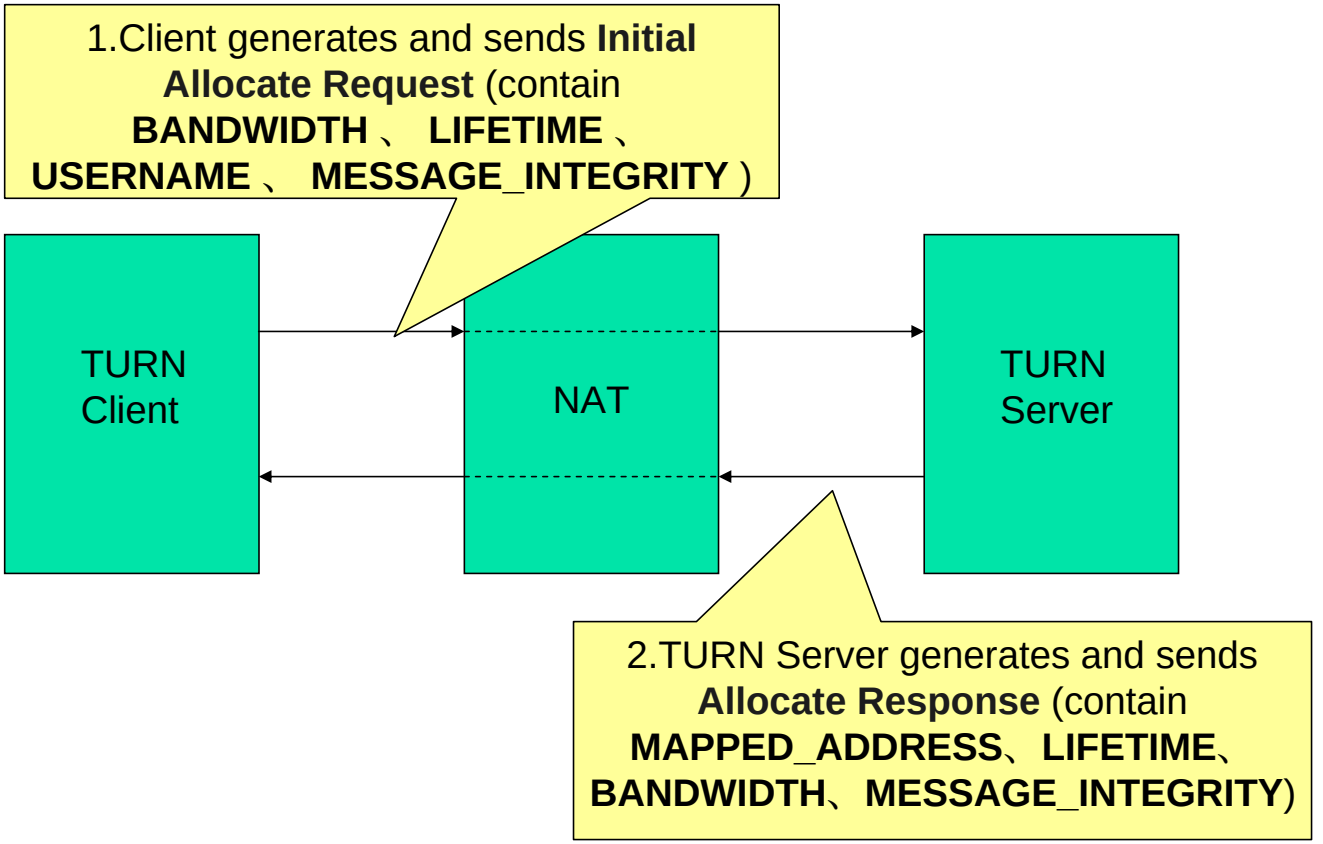
- Traversal Using Relay NAT
- draft-rosenberg-midcom-turn-06.txt



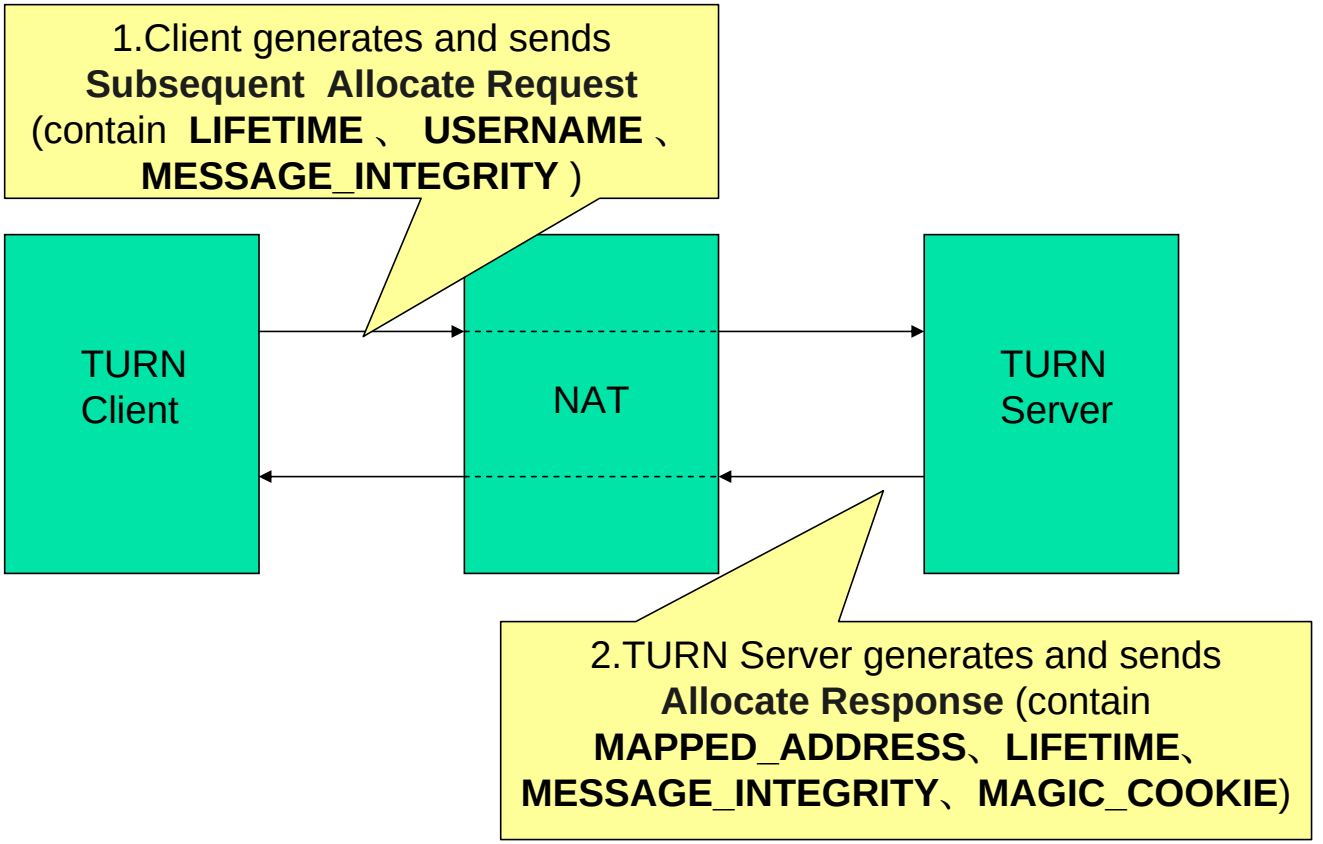
Obtaining a One Time Password



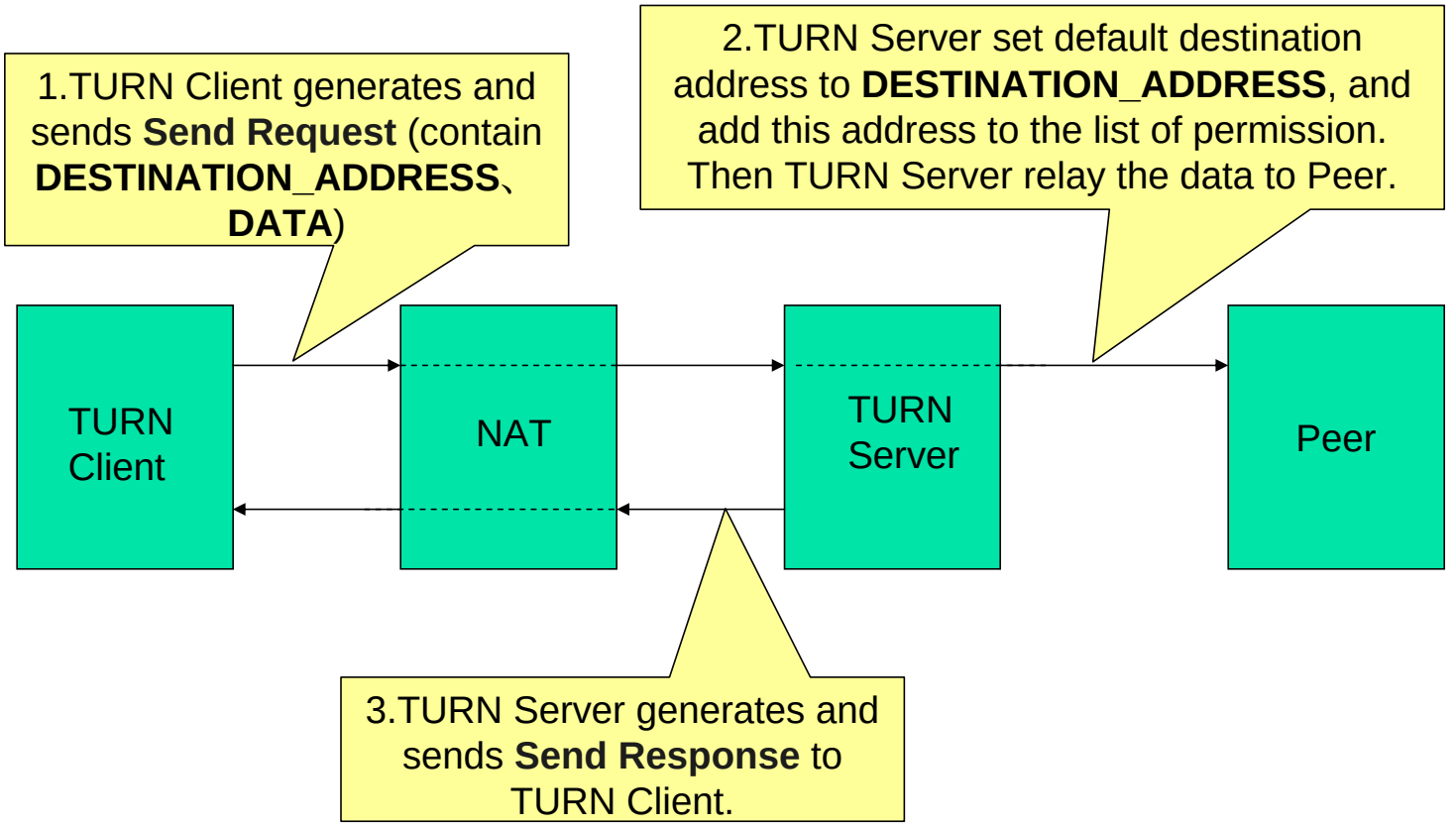
Allocating a Binding



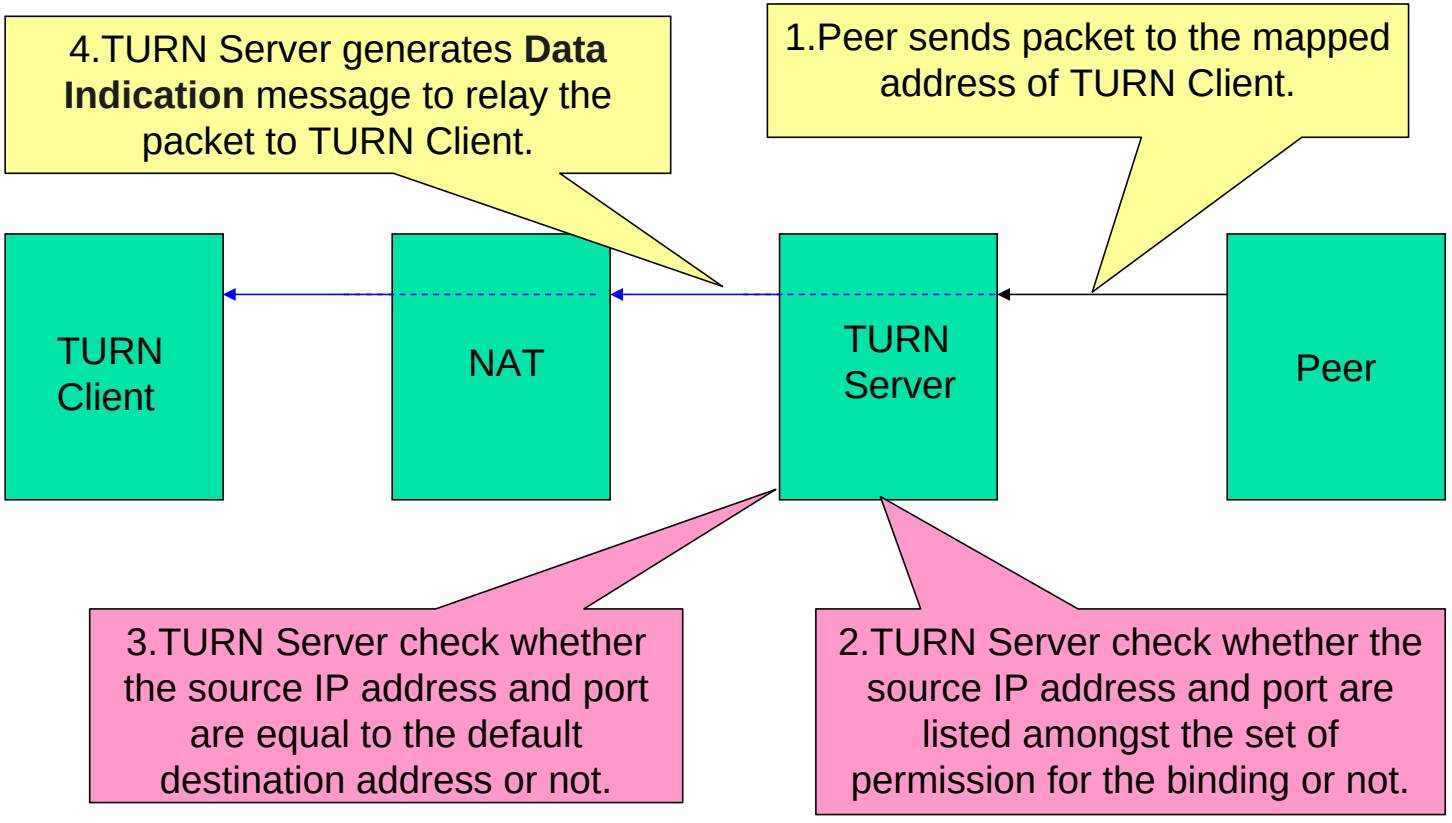
Refreshing a Binding



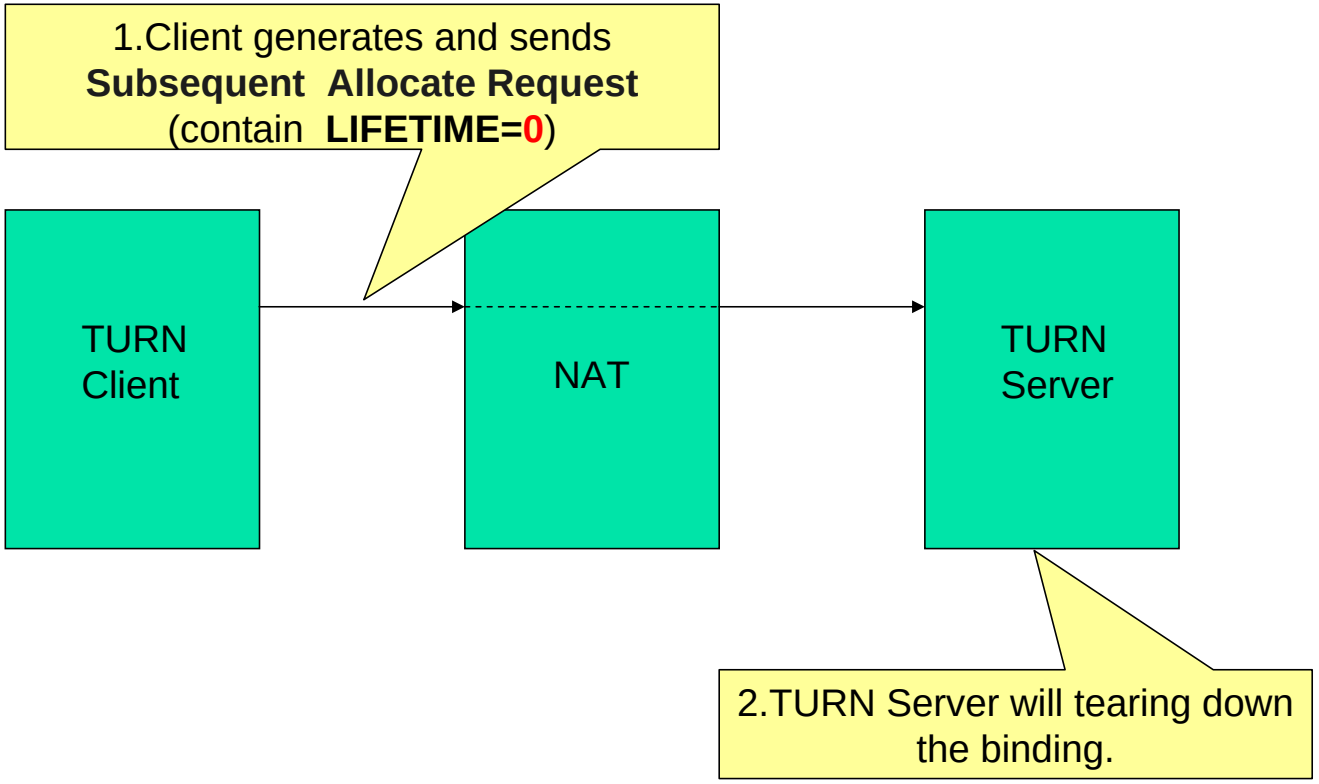
Sending Data

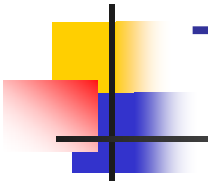


Receiving Packet



Tearing Down a Binding





TURN – Pros and Cons

- Pros
  - No change required in NAT.
  - Work through firewall and all kinds of NAT.
- Cons
  - Long latency
  - Heavy load for TURN server