Characterization and Measurement of TCP Traversal Through NATs and Firewalls

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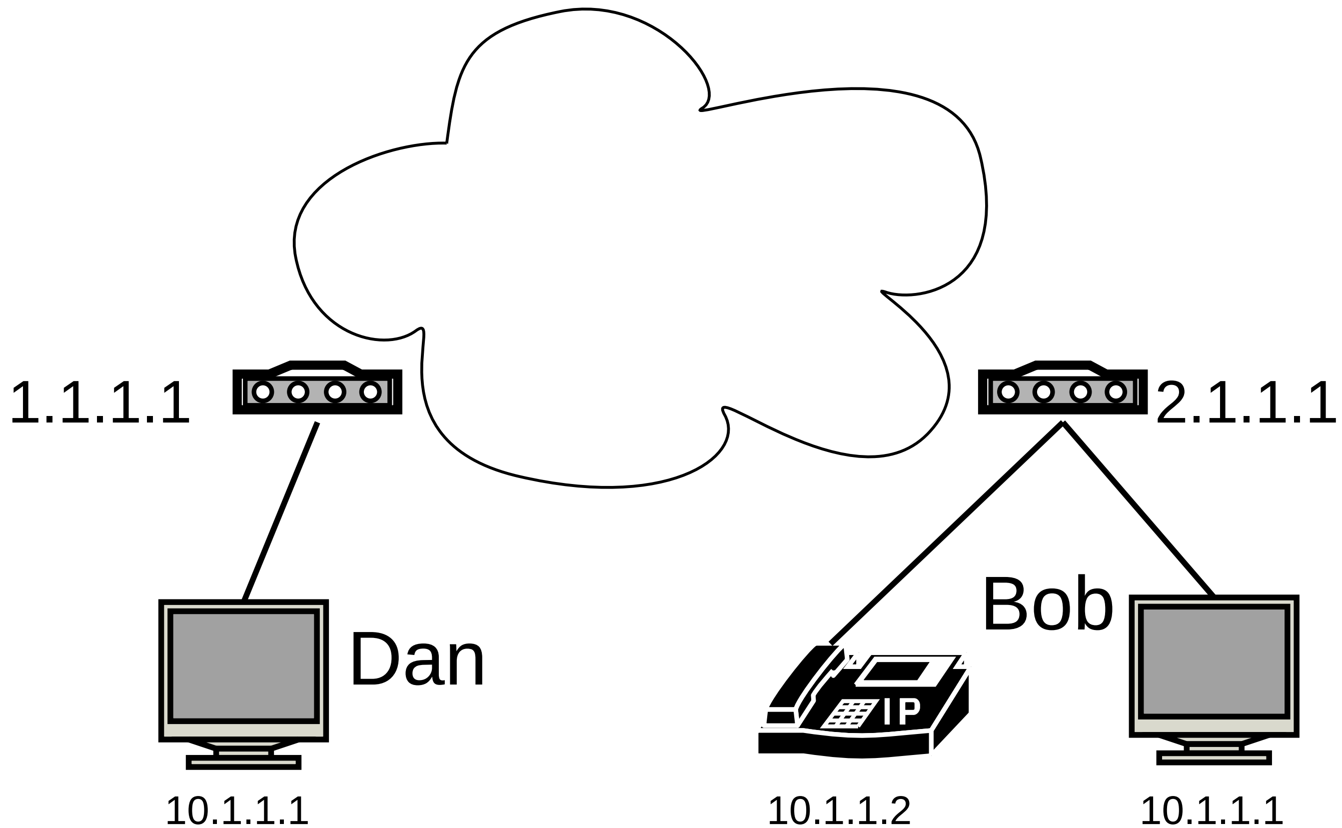
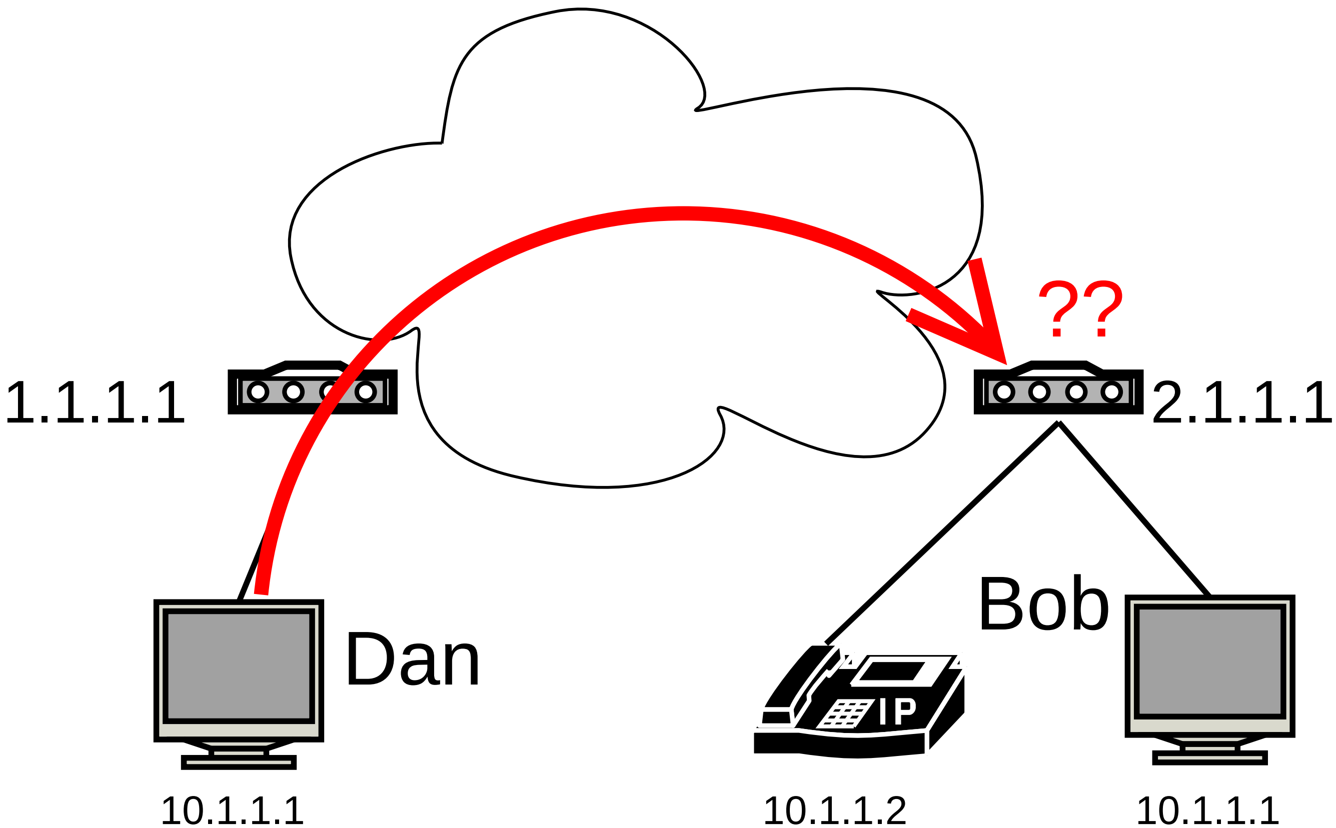
IMC 2005

P2P connectivity through NATs



New inbound flows cannot be routed

P2P connectivity through NATs



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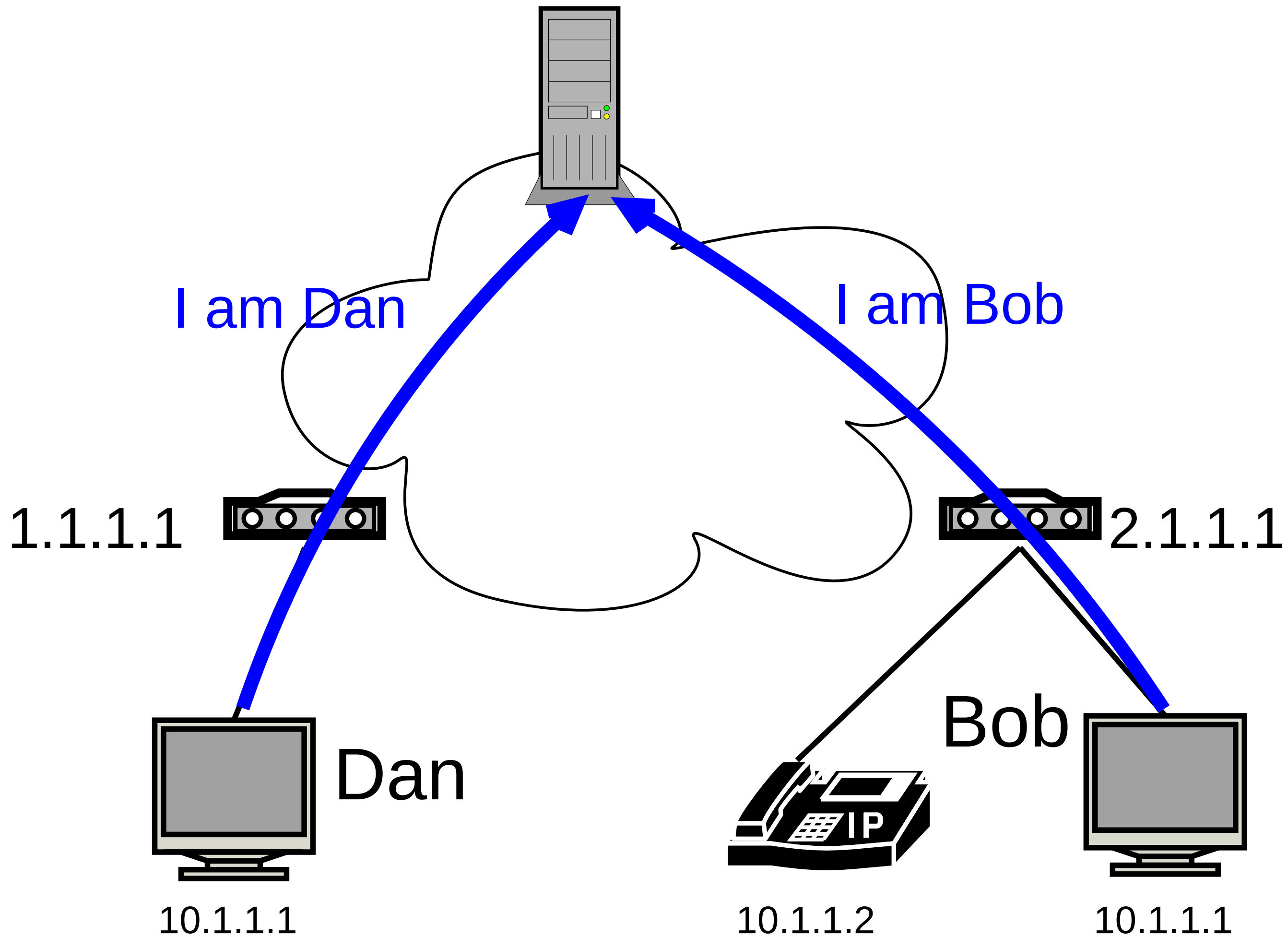
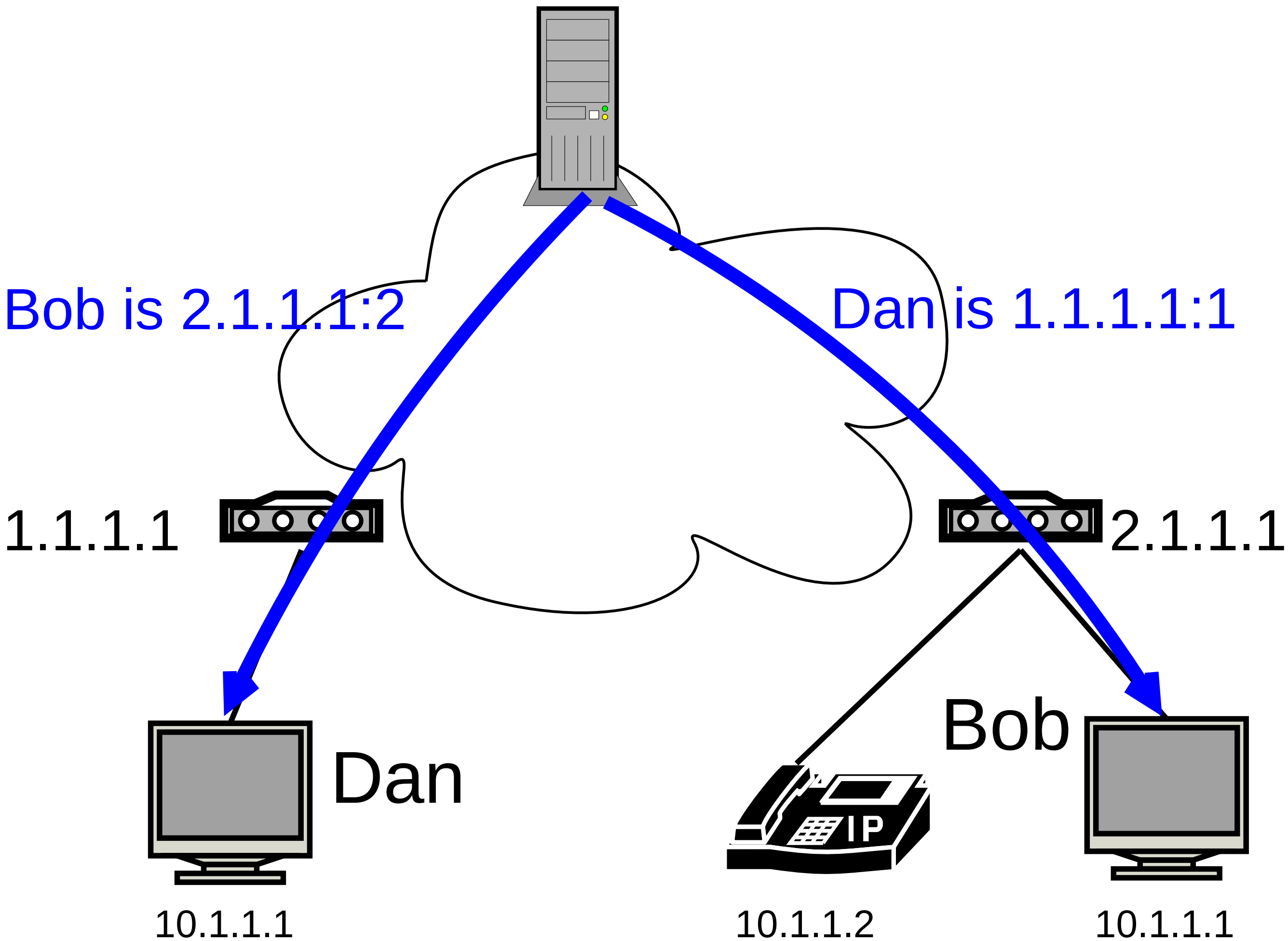


Basic solution for UDP

P2P connectivity through NATs



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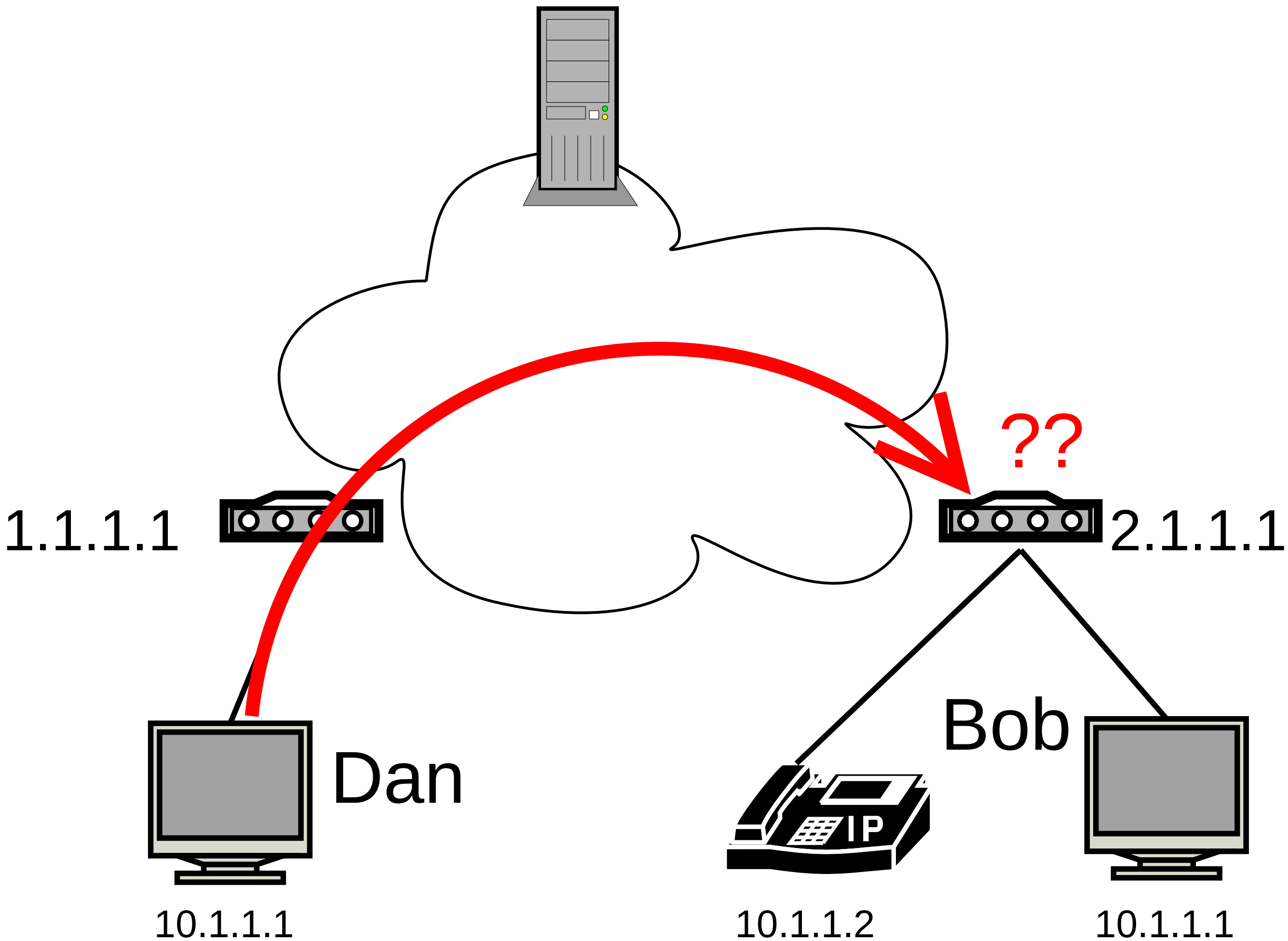

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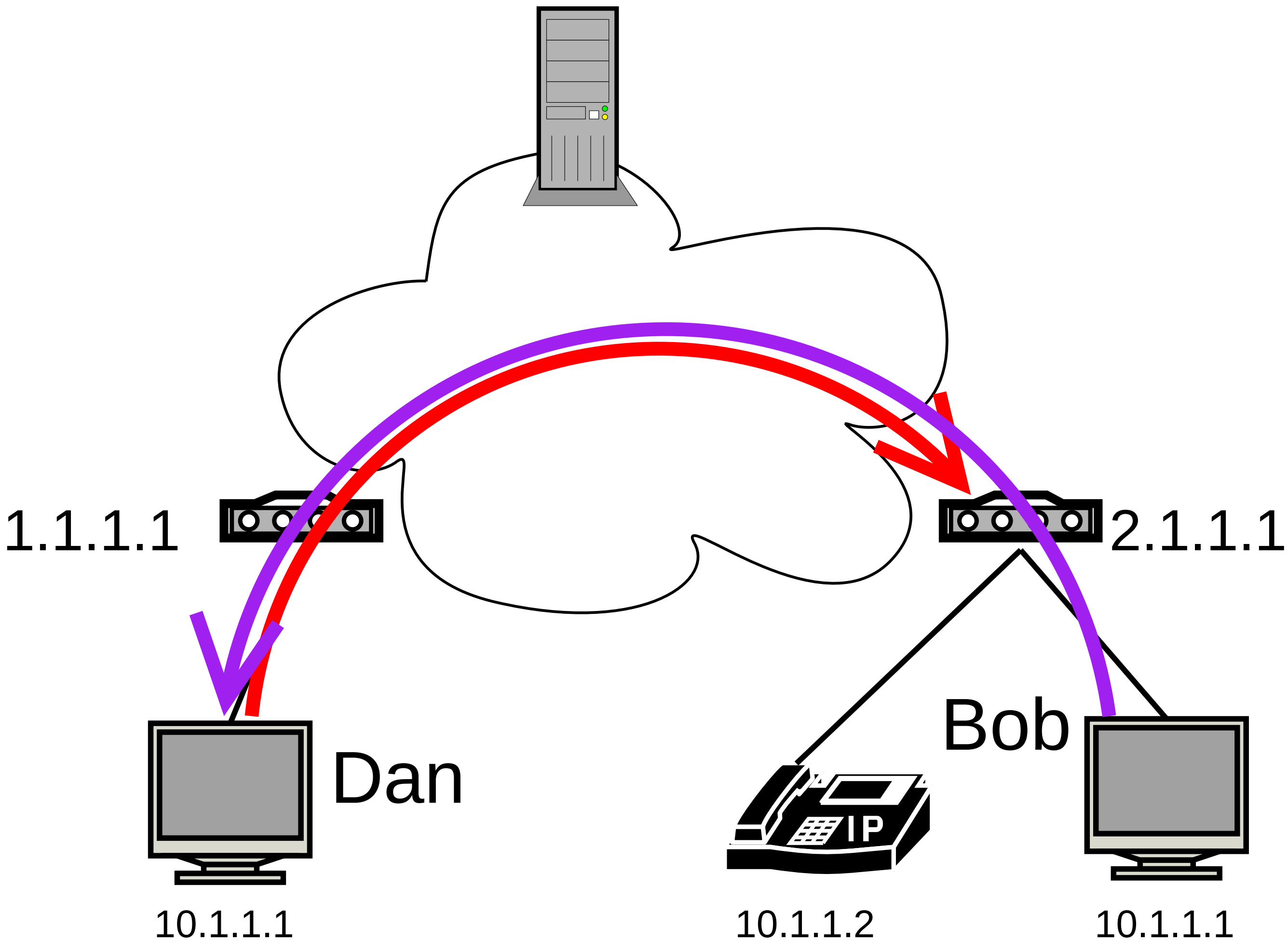

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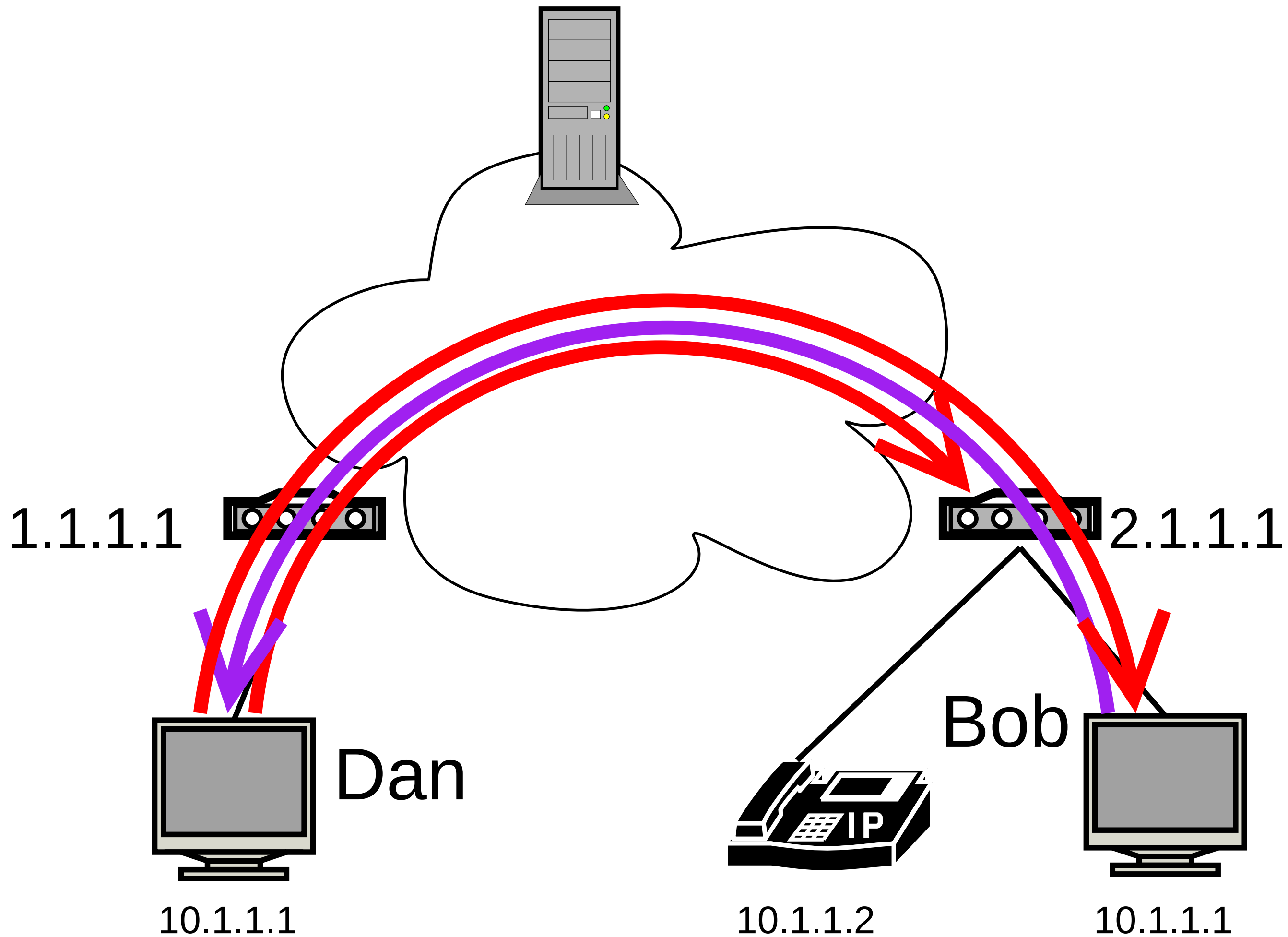

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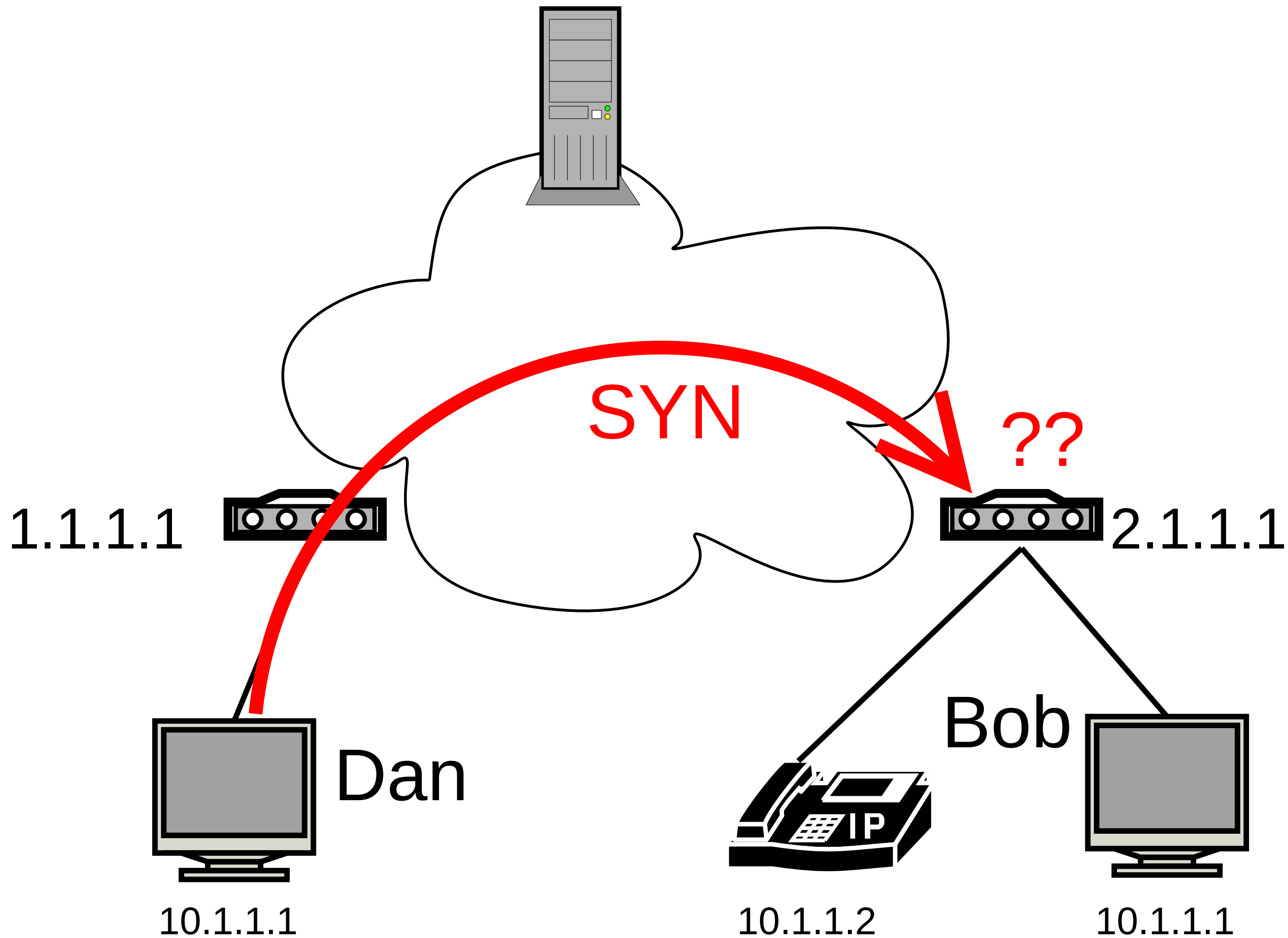
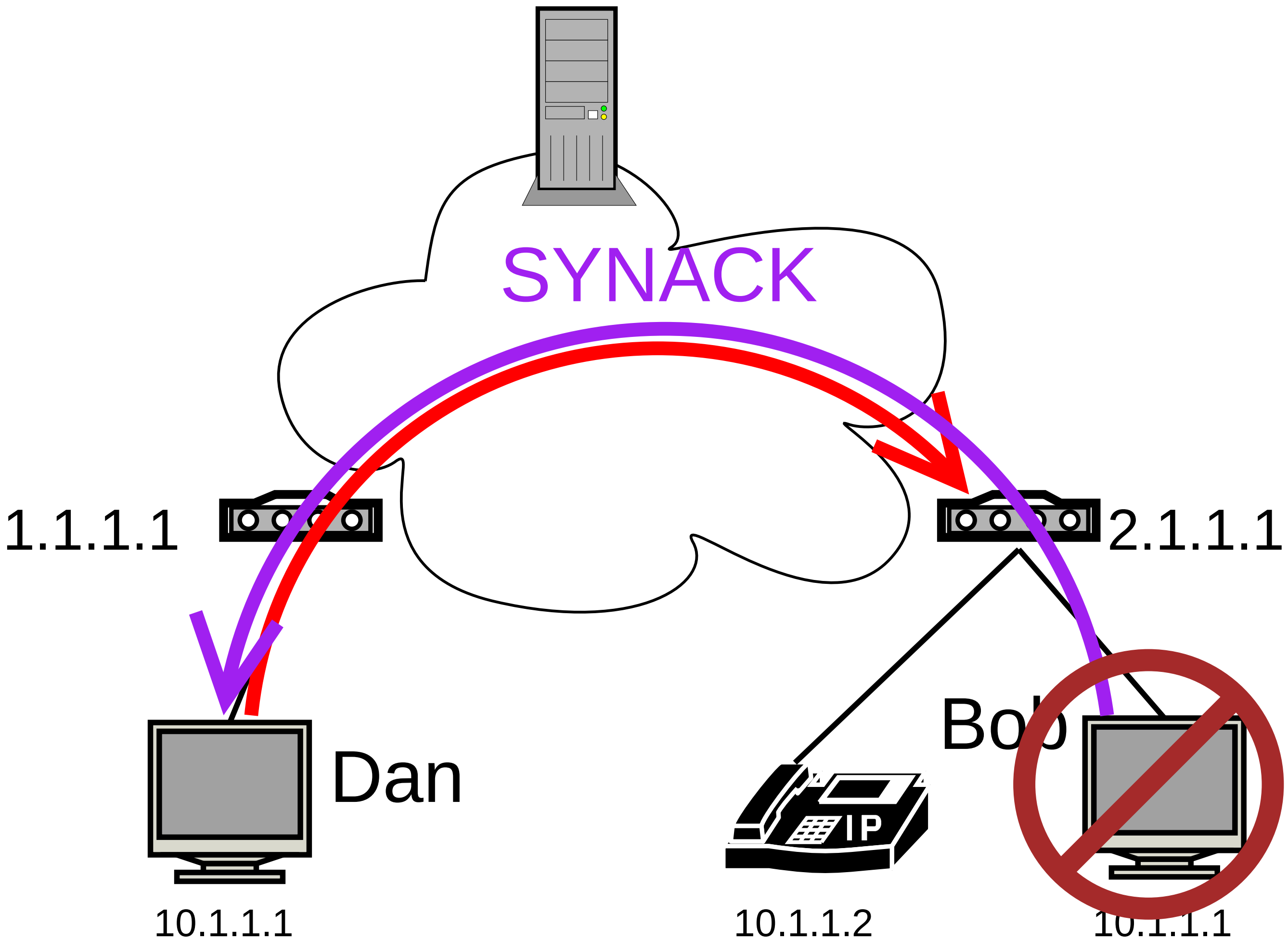


TCP establishment more complex

P2P connectivity through NATs



TCP establishment more complex

Context for this work

'92	NAT Invented
'93-'96	NAT traversal presumed impossible
'97-'01	UDP traversal solved and standardized [Kegel]
'93-'03	TCP traversal presumed impossible
'04	TCP traversal 'solved' (2 approaches) [Guha]
'05	2 more approaches [Ford, Biggadike]
'05	Approaches evaluated [Guha]
'06	TCP traversal standardized

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’9	
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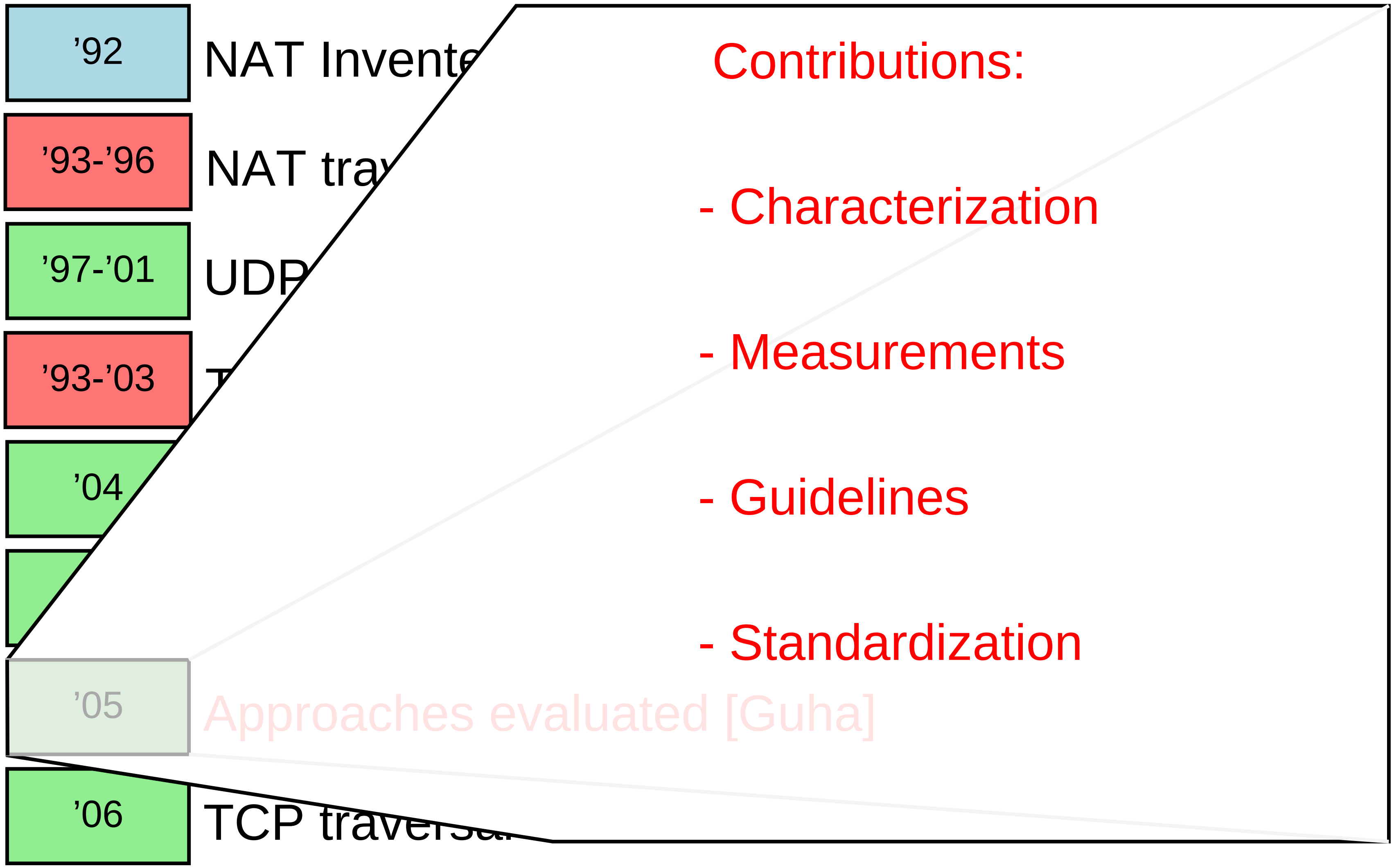
’05	
’06	TCP traversal

4 approaches

Many trade-offs

- NAT sensitivity
- Ease of Implementation
- Ease of Deployment

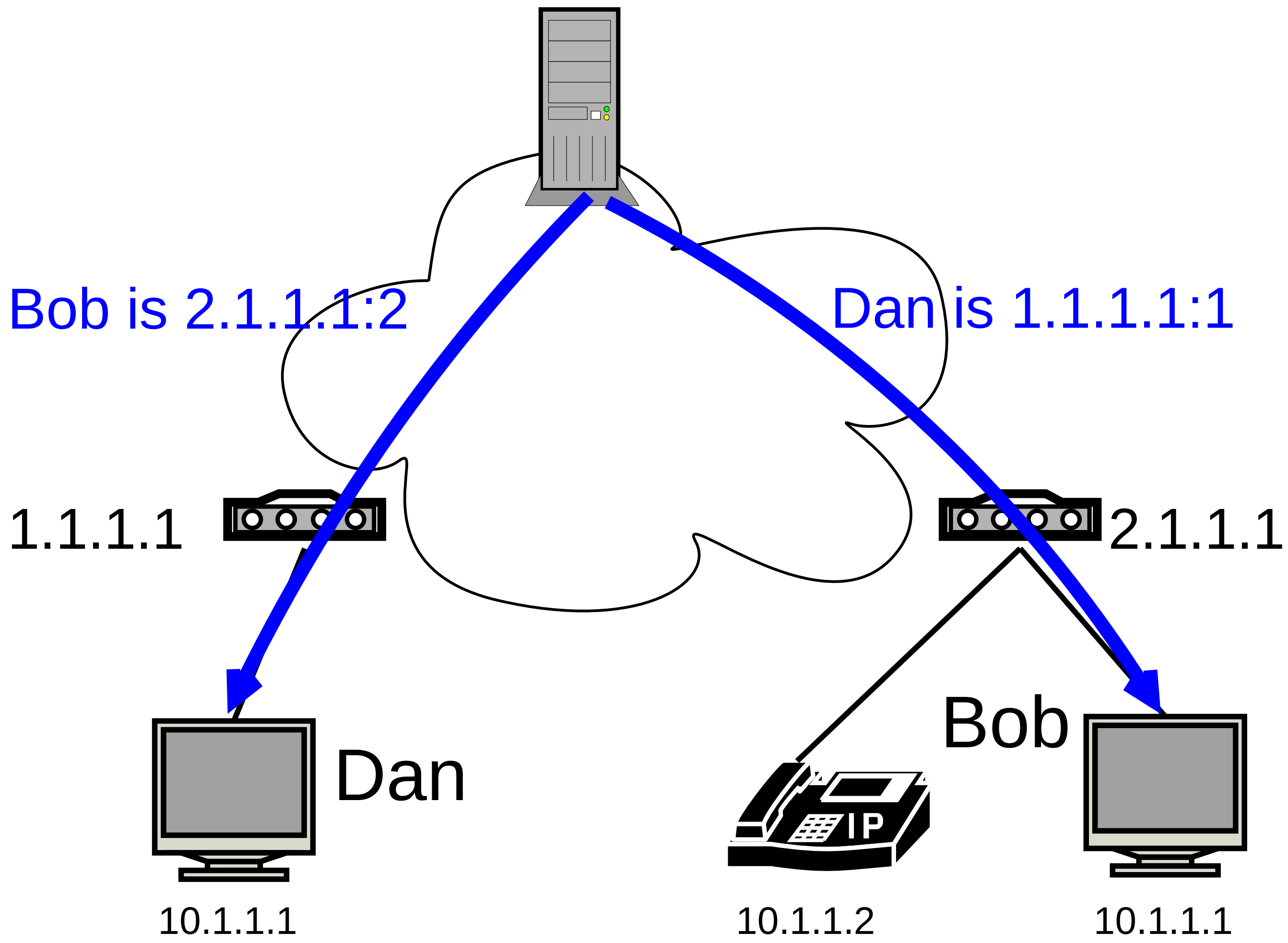
Context for this work



“Take away” Results

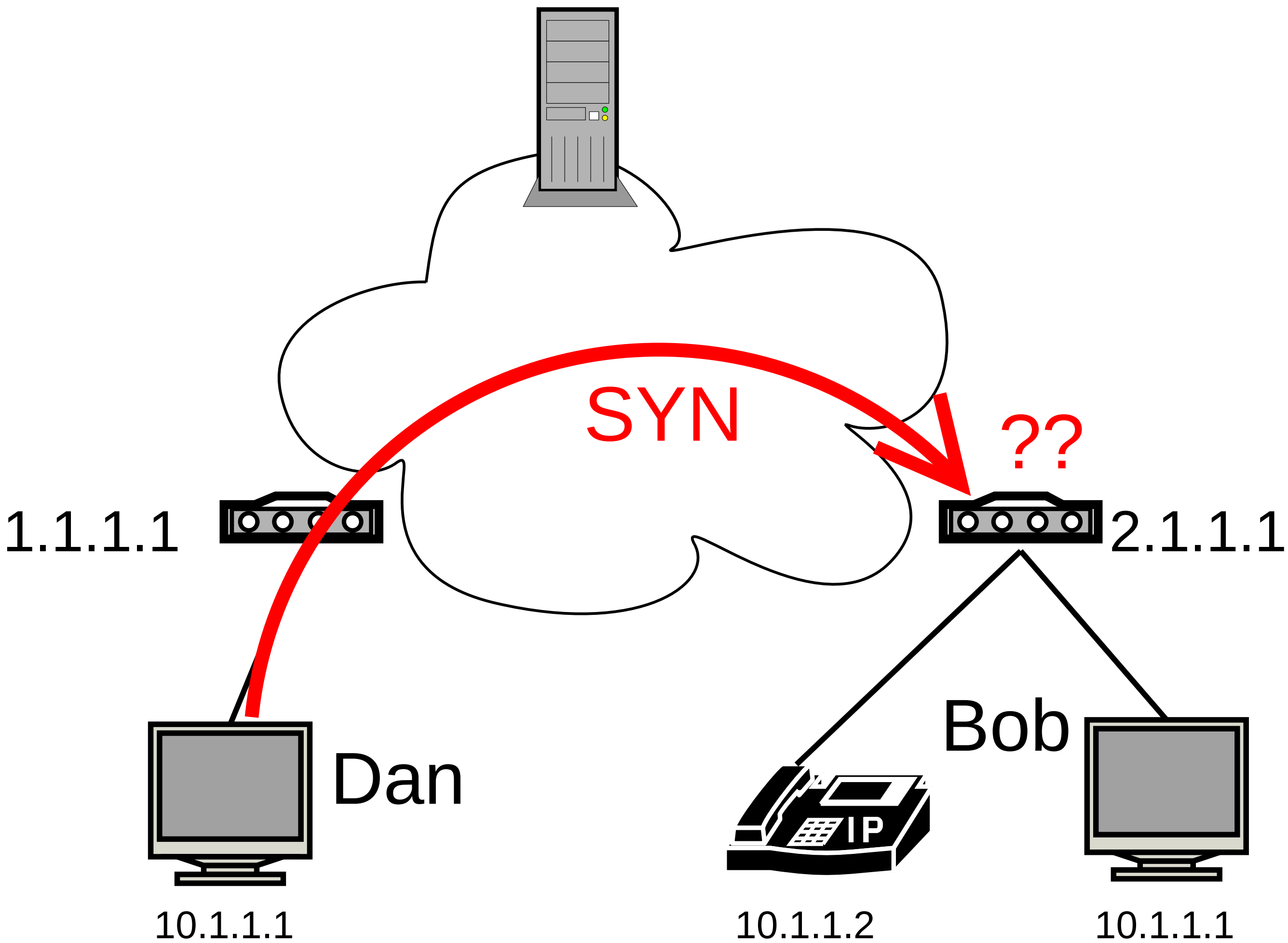
- TCP can be established between NAT’ed peers
- Works an estimated 85%–90% of the time today
- 100% for certain popular, well-behaved NATs
    - All NATs could standardize to this

P2P TCP Establishment



Use Rendezvous Service

P2P TCP Establishment



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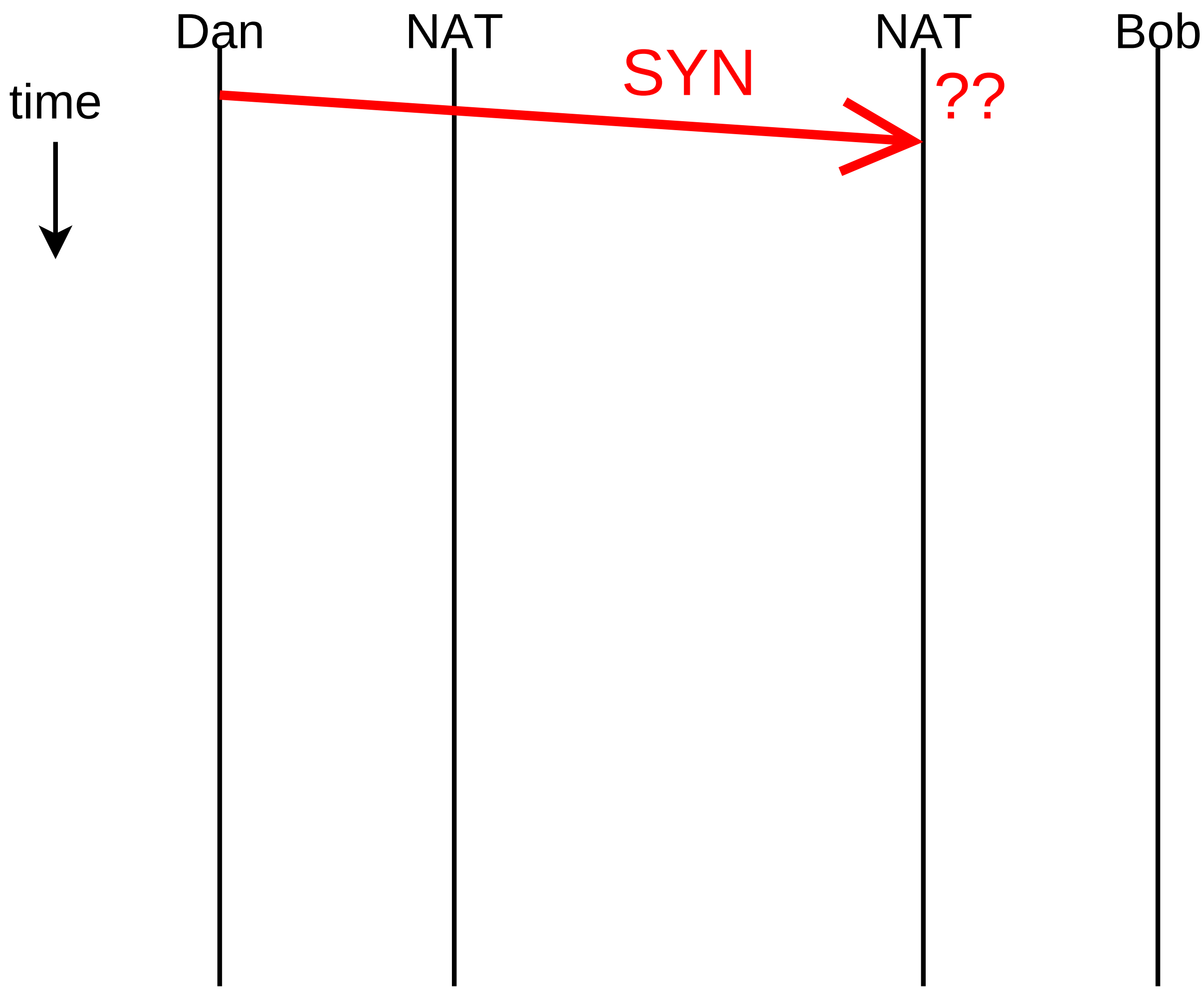
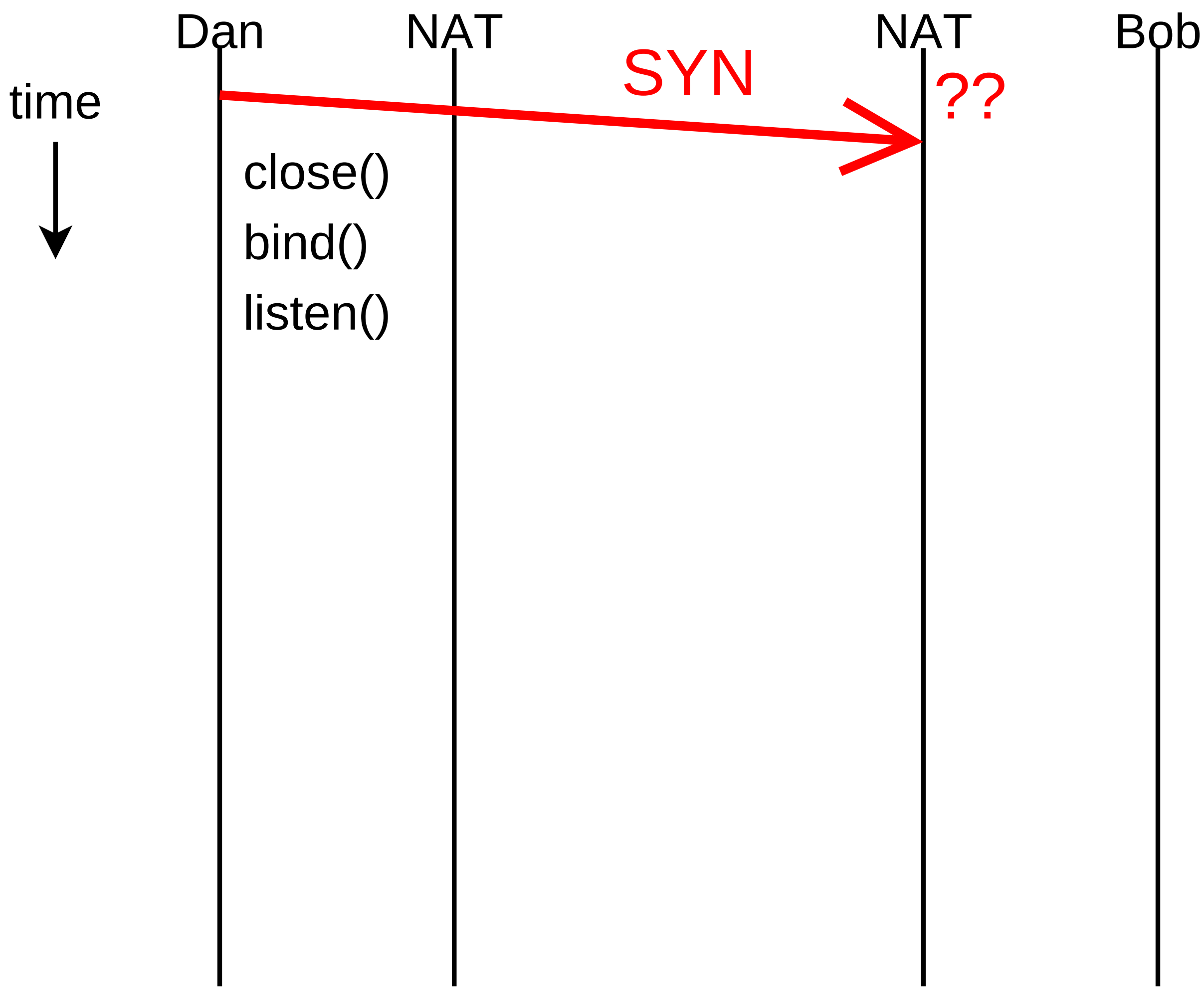


Punch hole using connect/close/bind/listen

P2P TCP Establishment



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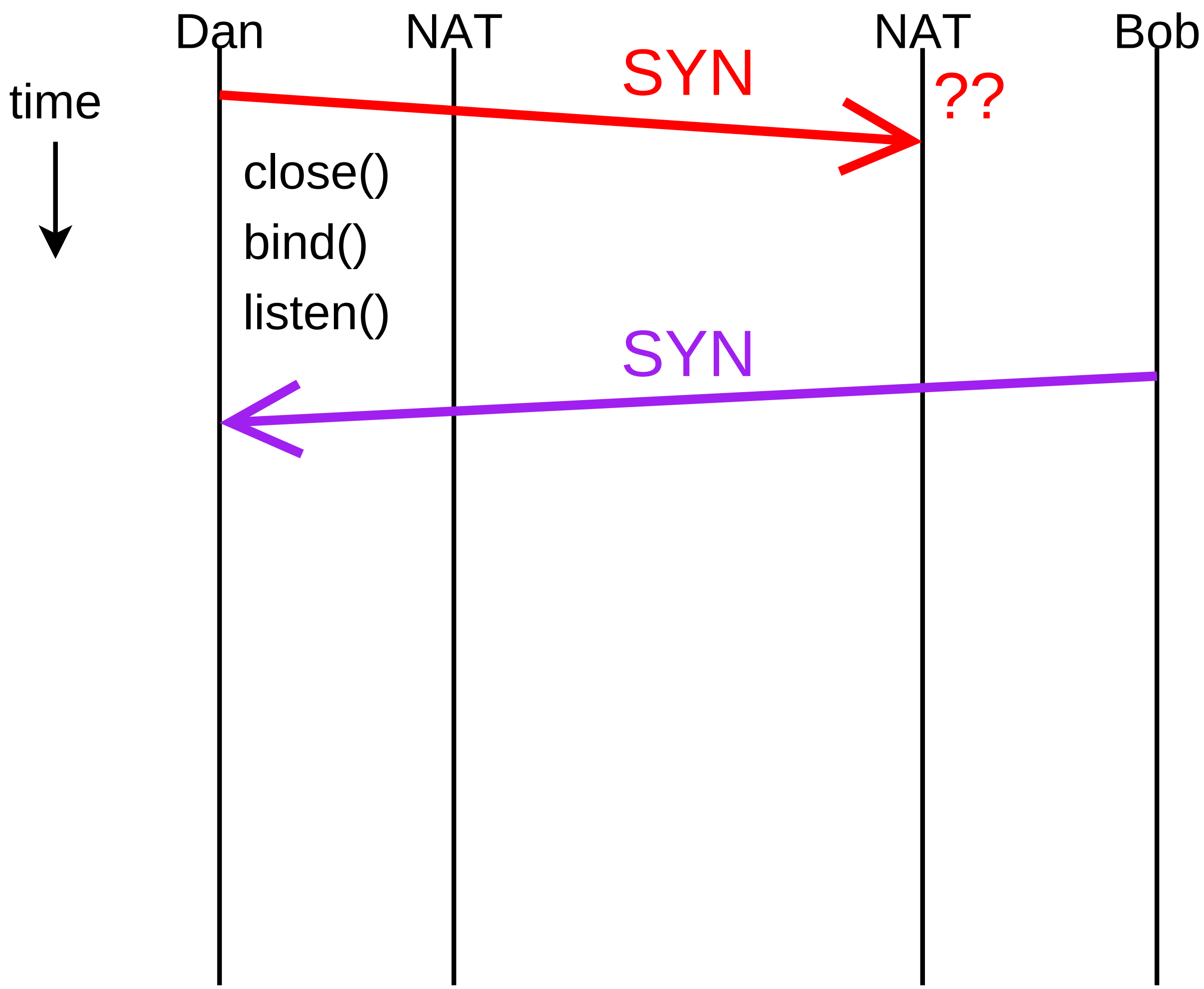
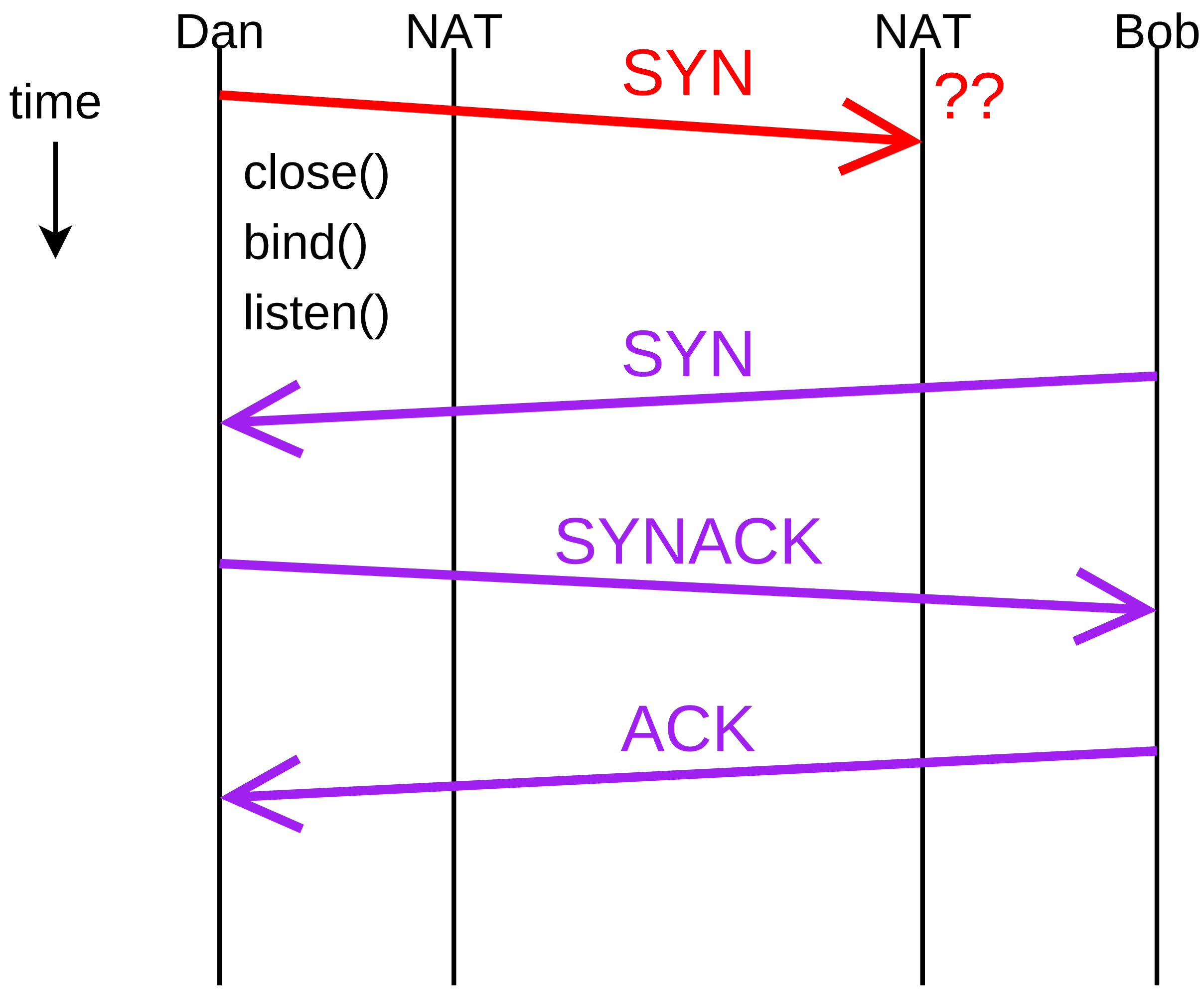


Accept incoming connection

P2P TCP Establishment



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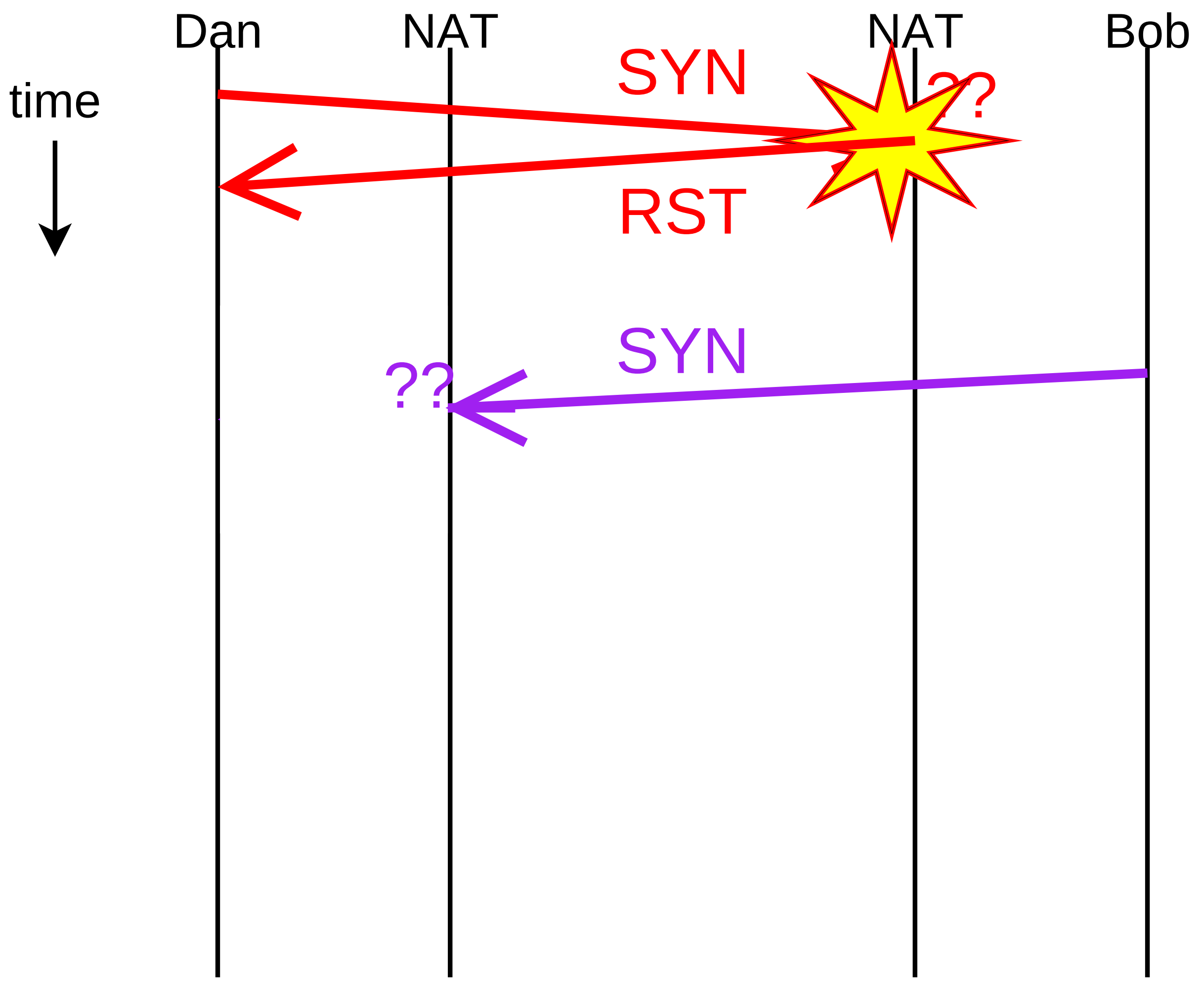
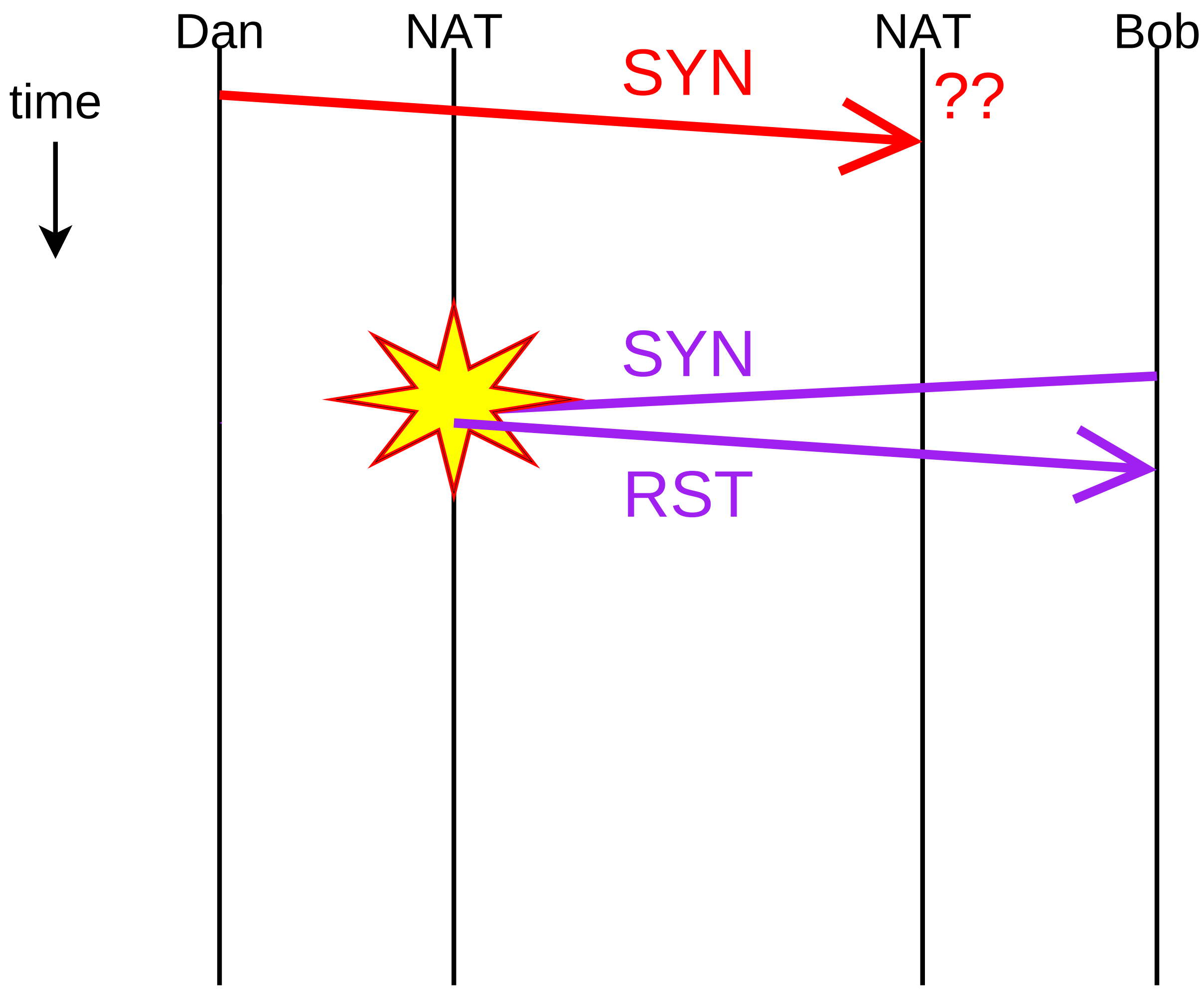


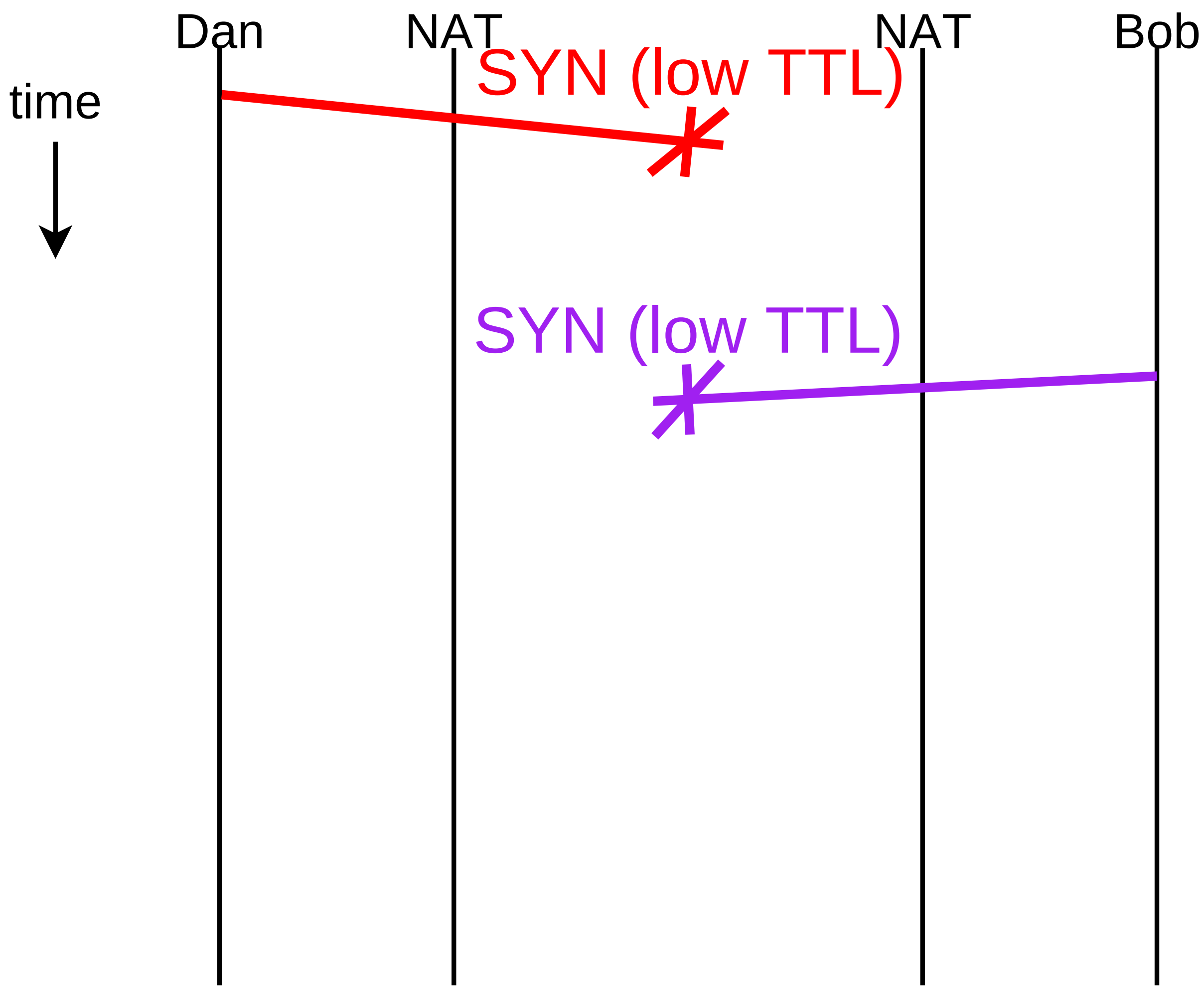
What if: NAT returns RST, closes hole

P2P TCP Establishment



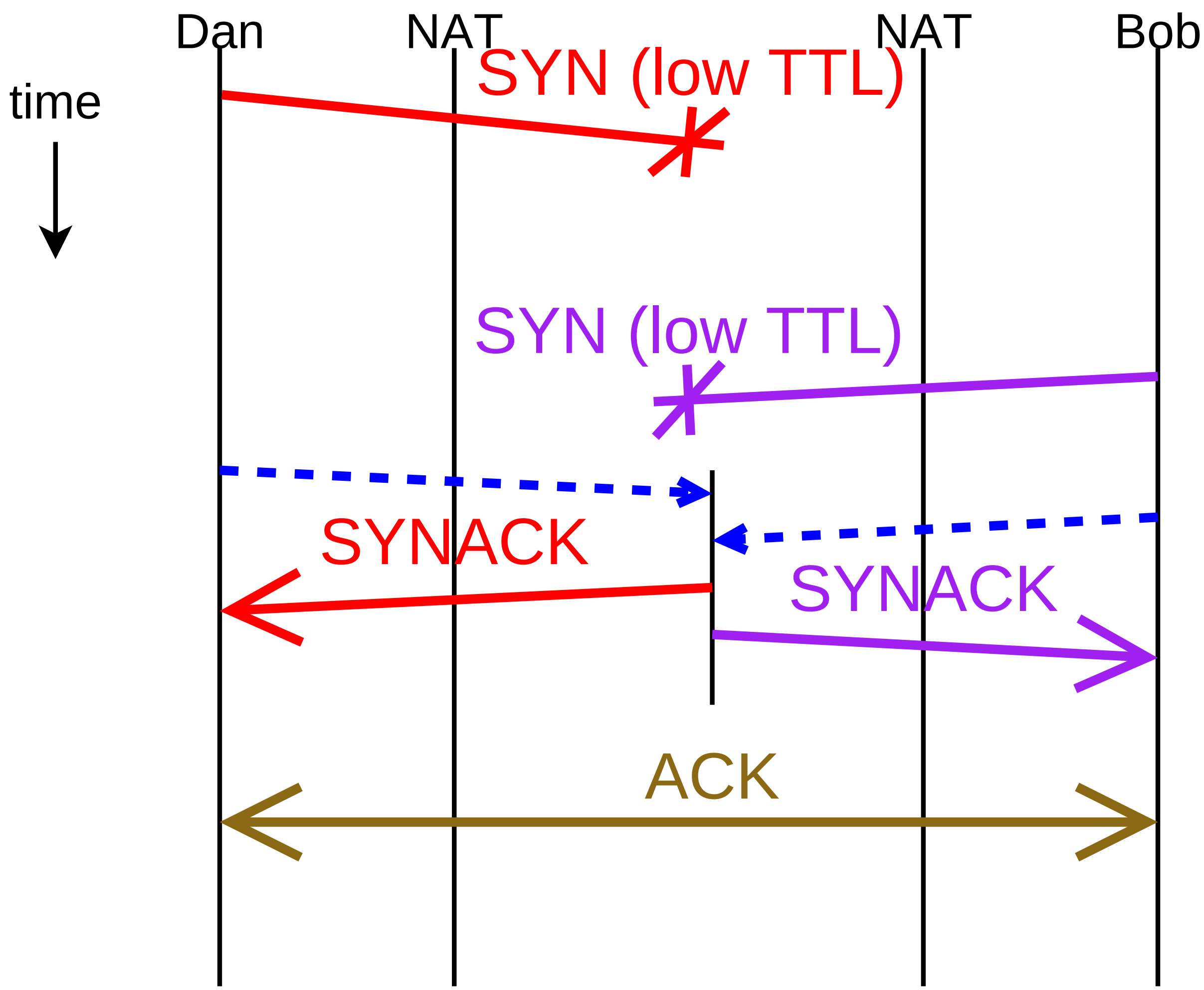
What if: NAT rejects SYN through hole

P2P TCP Establishment



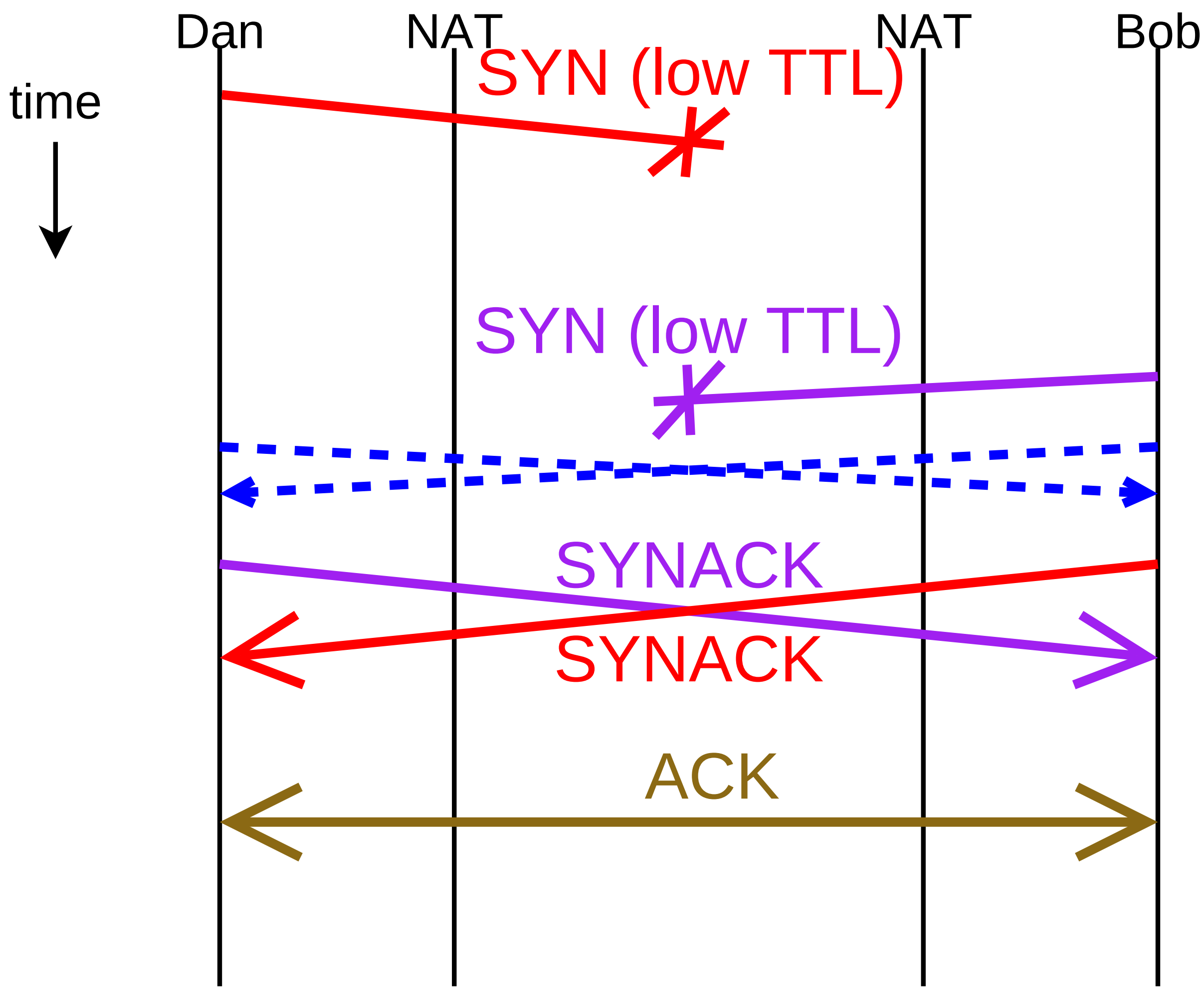
Variation: low-TTL SYN

P2P TCP Establishment



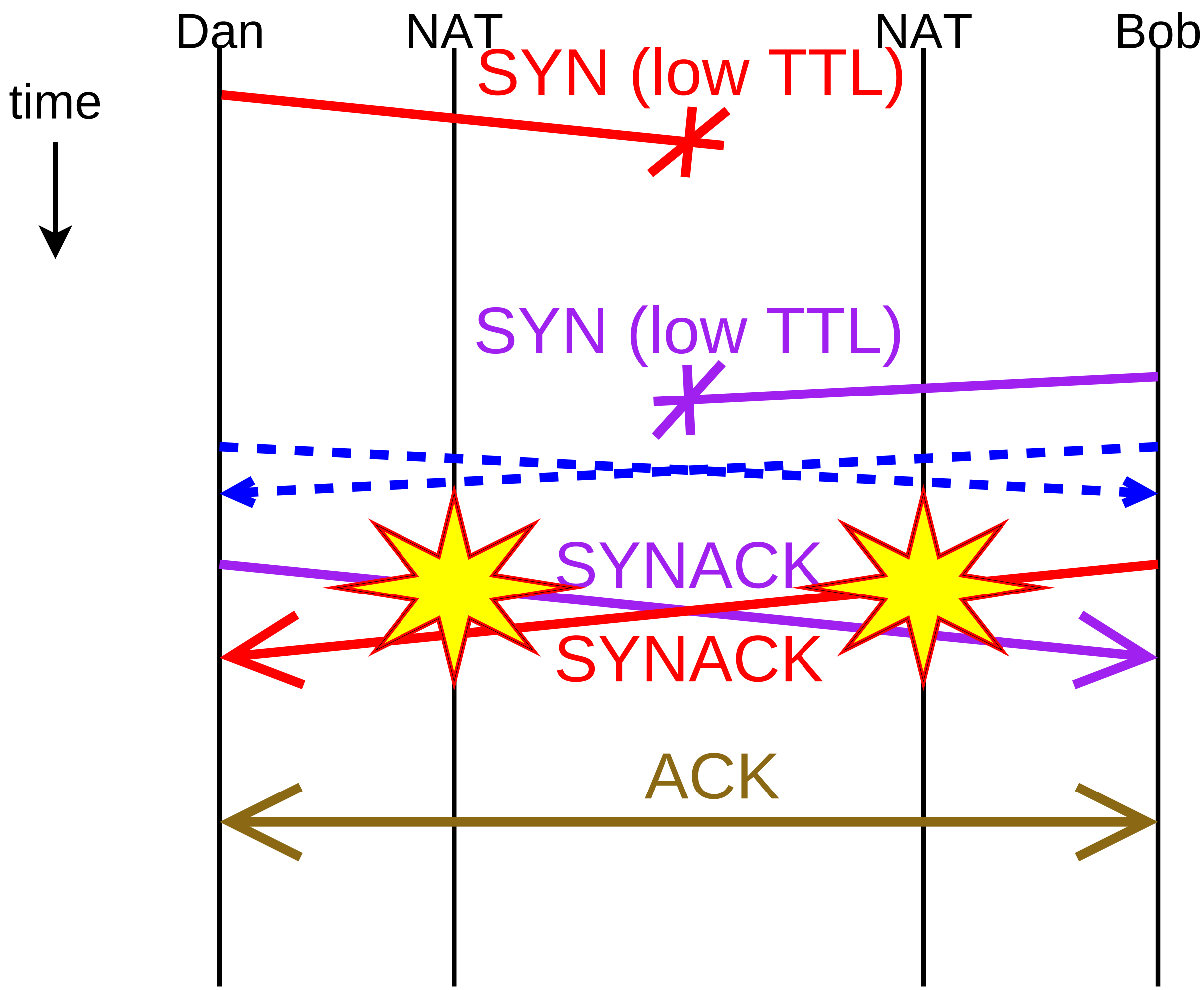
Variation: low-TTL SYN, spoof SYNACK

P2P TCP Establishment



Variation: low-TTL SYN, RAW SYNACK

P2P TCP Establishment



What if: NAT blocks outgoing SYNACK

Recap

- 4 approaches
  - 16 variants (mix and match)
- Many trade-offs
  - Some sensitive to NATs behavior
  - Some hard to implement
  - Some hard to deploy
- Measurement study to determine how well each works in practice

Methodology

- Implemented all approaches
  - Lessons learned in the paper
- Cause of failure for 16 brands of NATs
  - Linksys, DLink, Netgear, Belkin, . . .
- 32 axis of classification
- Classified ($\sim$100) NATs in the wild
- Extrapolated for world-wide behavior
  - Brand share market analysis

NAT Axes of Classification

NAT Binding:		
Type	Delta	Hairpin
Overloading	Max Flows	Predictable
Preservation:		
Port Number	Low	High
Dynamic	Parity	Sequential
Packet Mangling:		
TCP Data	ICMP Data	TCP Sequence
IP TTL		
Filters:		
$\overleftarrow{SYN}$	$\overleftarrow{SYN}$ (known IP)	Estd. $\overleftarrow{SYN}$
$\overrightarrow{SYN}$ $\overleftarrow{SYN}$	$\overrightarrow{SYN}$ $\overleftarrow{RST}$ $\overleftarrow{SYN}$	$\overrightarrow{SYN}$ $\overleftarrow{ICMP11}$ $\overleftarrow{SYN}$
$\overrightarrow{SYN}$ $\overleftarrow{ICMP2}$ $\overleftarrow{SYN}$	$\overrightarrow{SYN}$ $\overleftarrow{SYNACK}$	$\overrightarrow{SYN}$ $\overleftarrow{RST}$ $\overleftarrow{SYNACK}$
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Timers:		
SYN-SENT	Established	Timed-Wait
RST		

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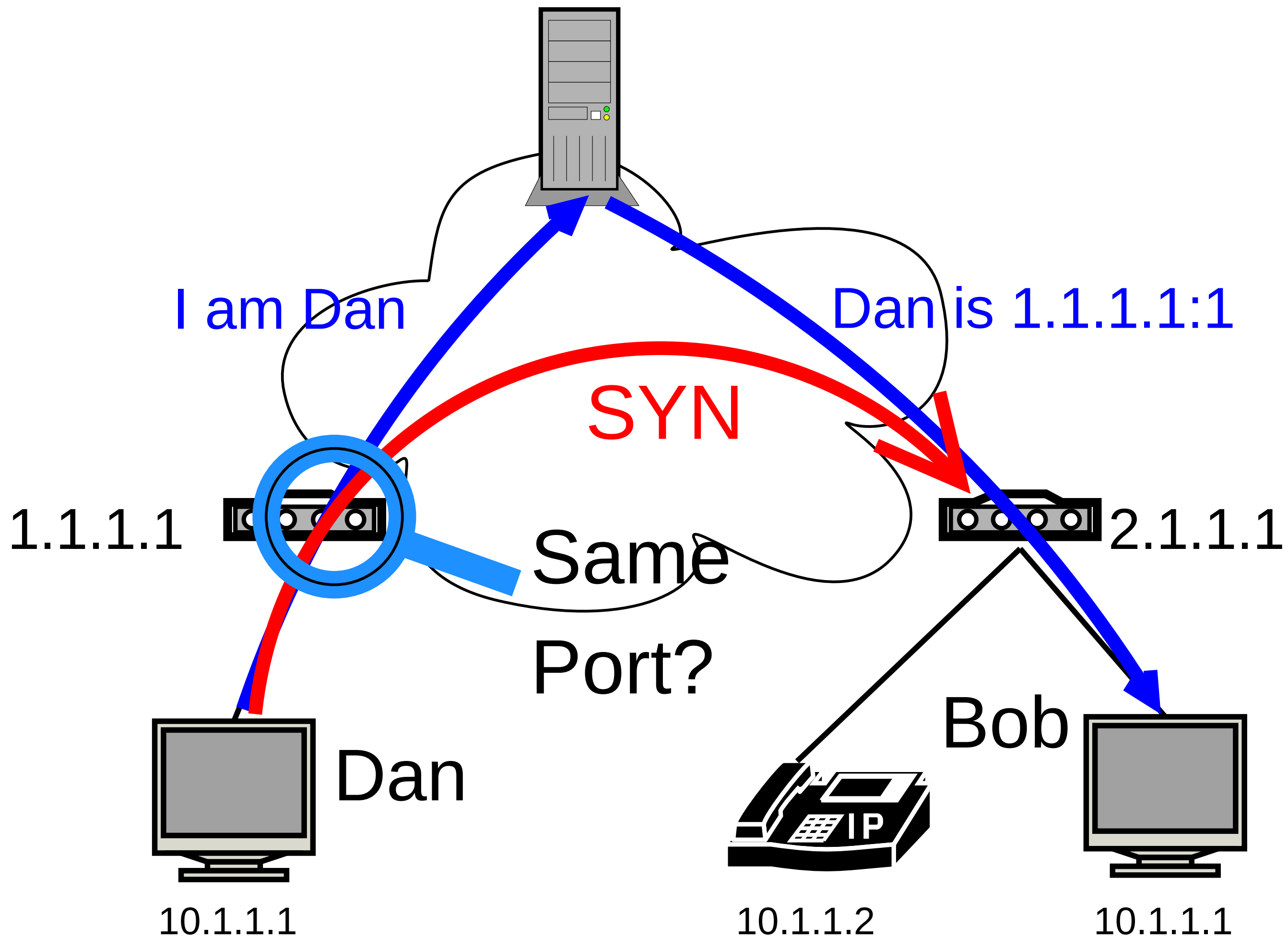
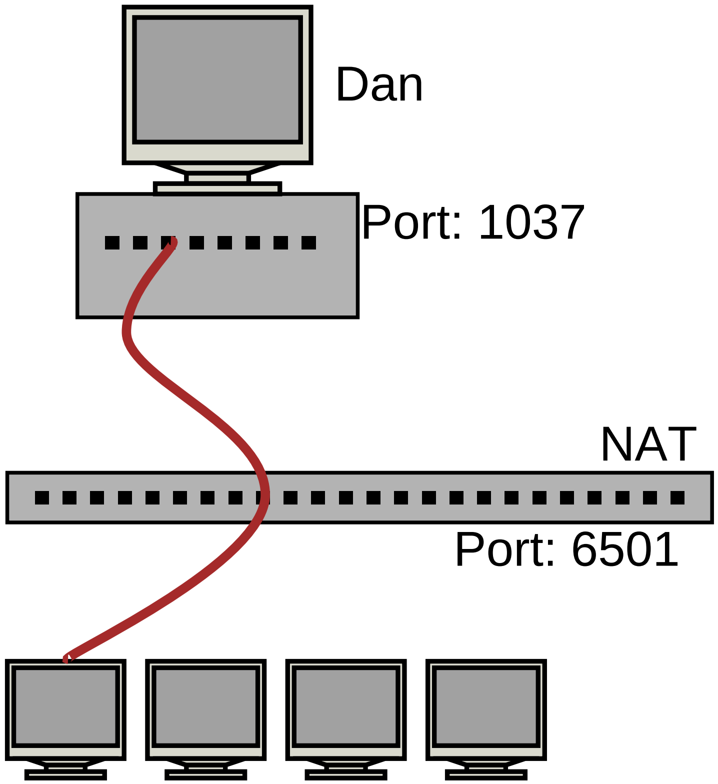
Port Prediction



Problem: What port did SYN come from?

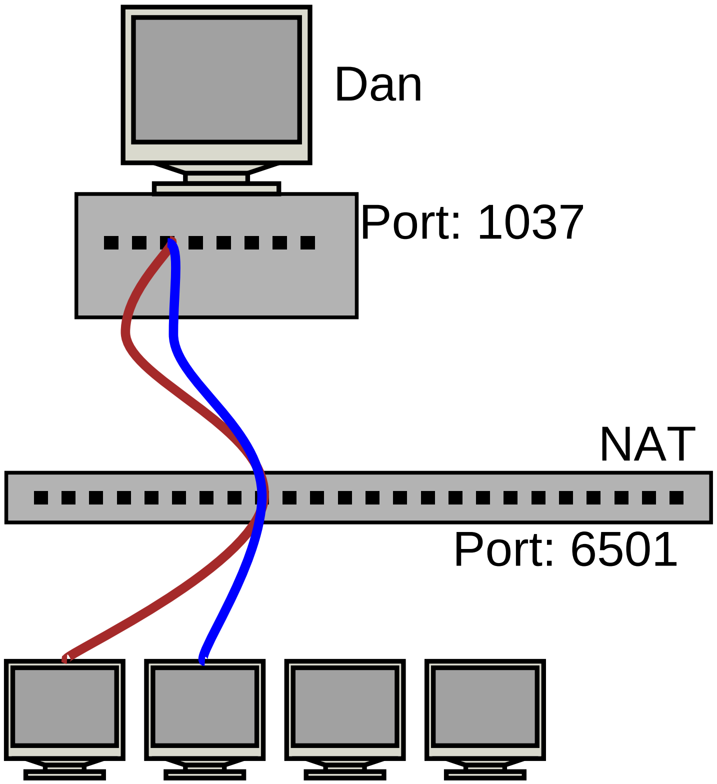
Port Prediction



Classification

NB:Independent

Port Prediction



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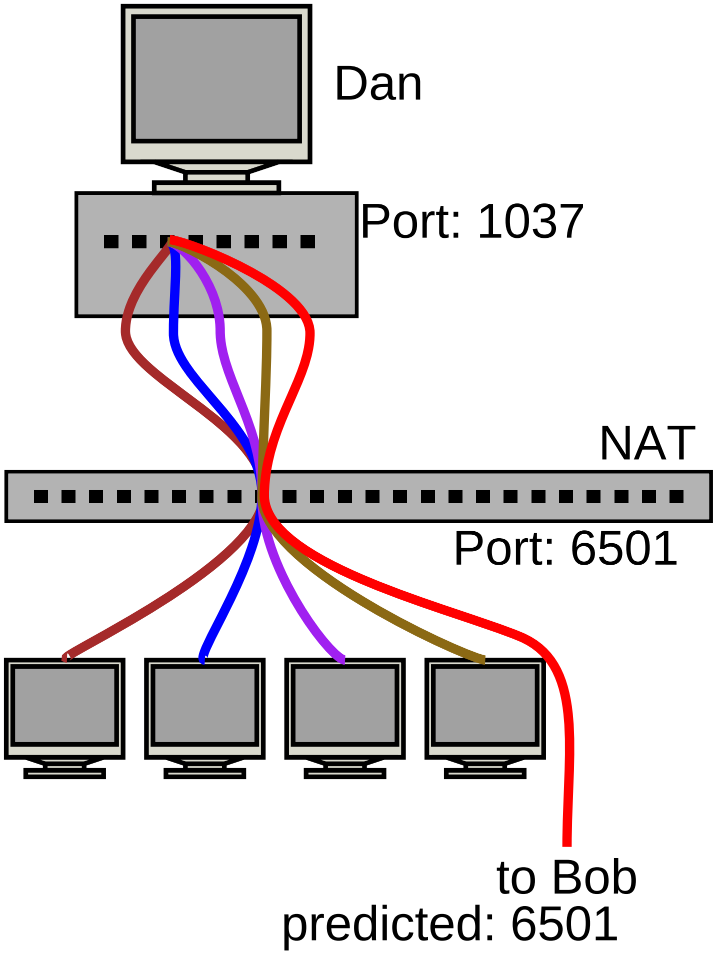

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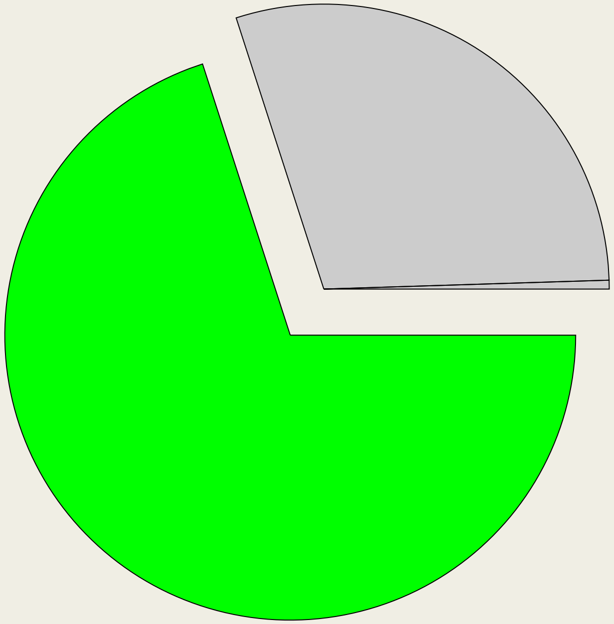

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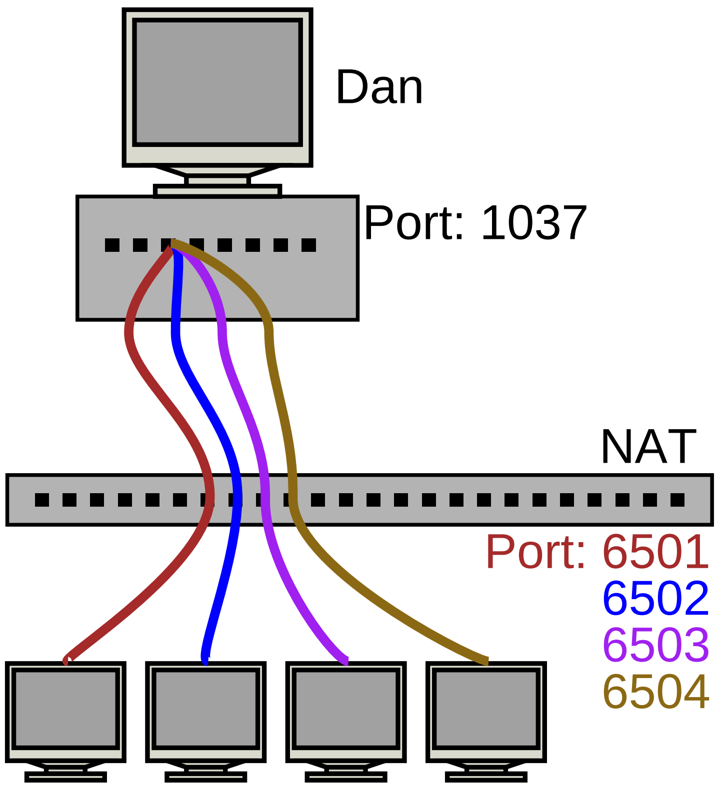

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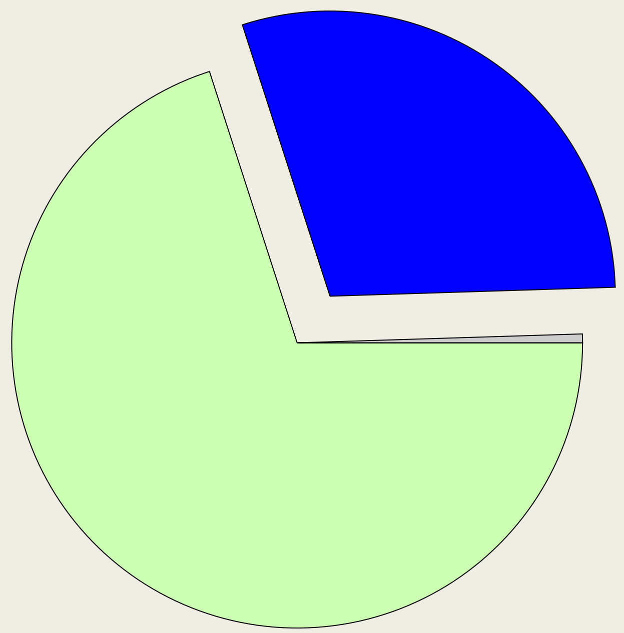

NB:Delta

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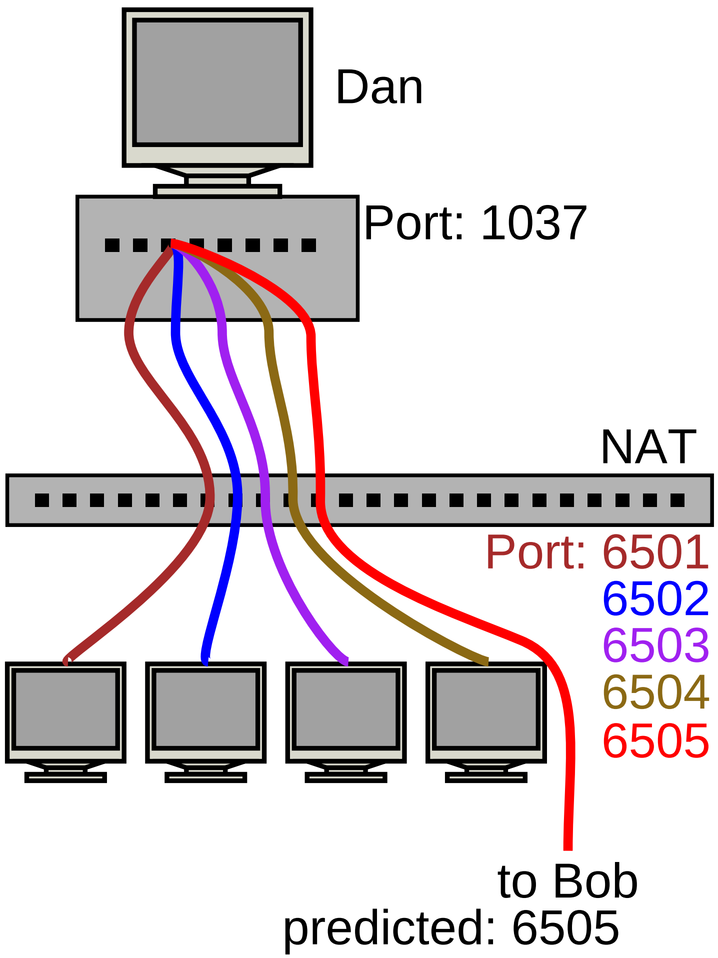

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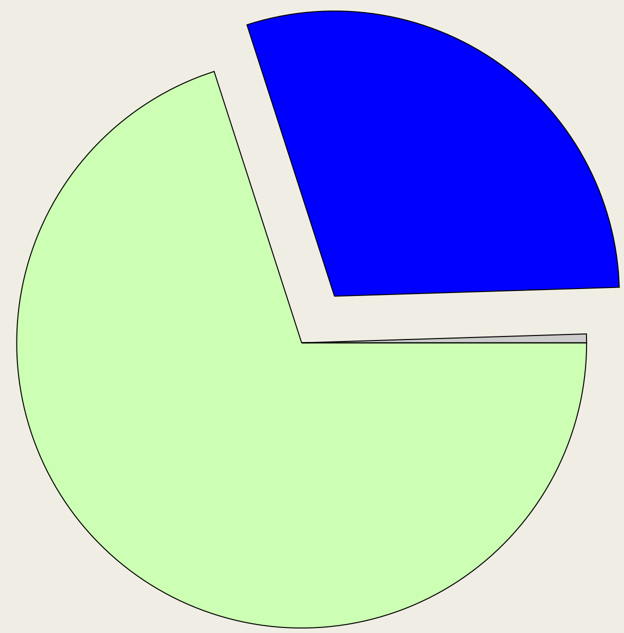

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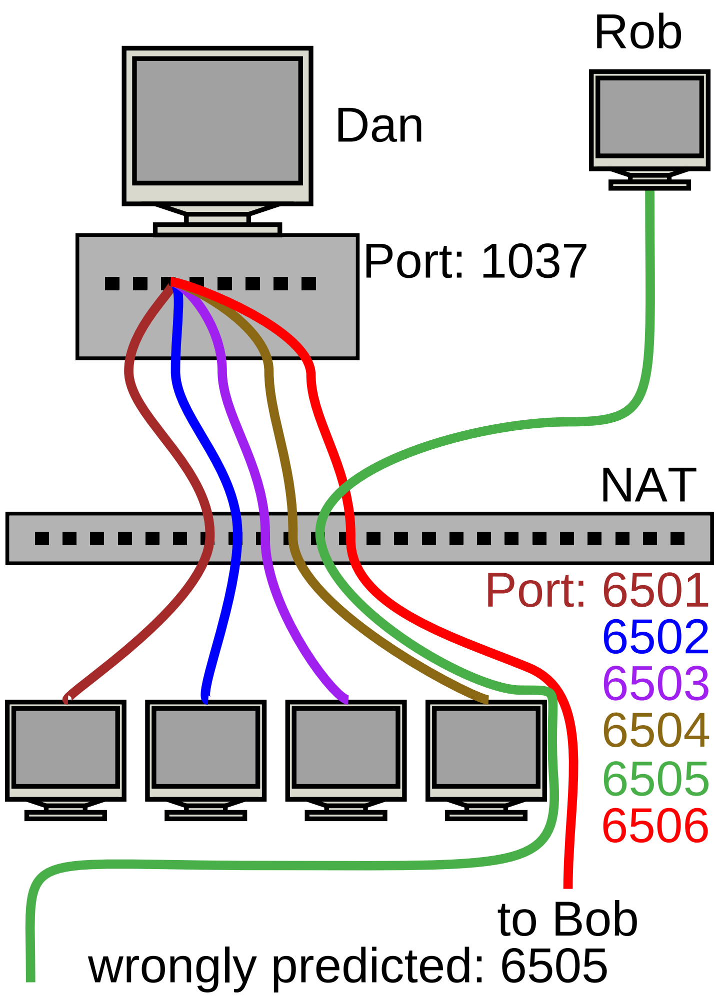

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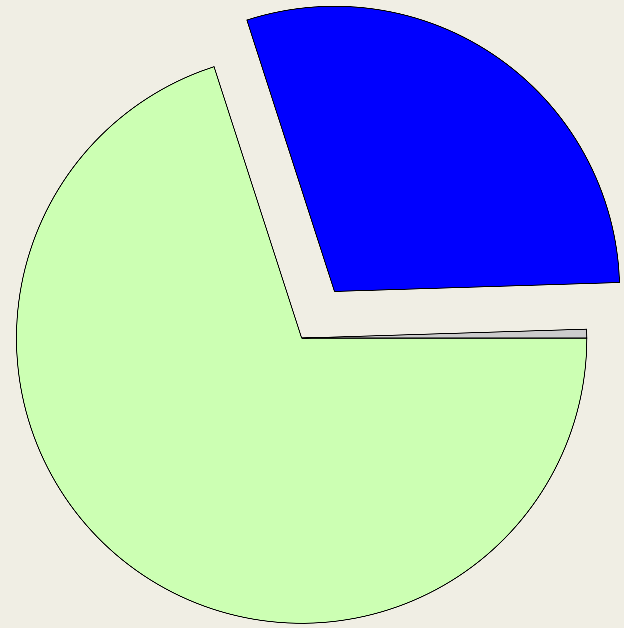

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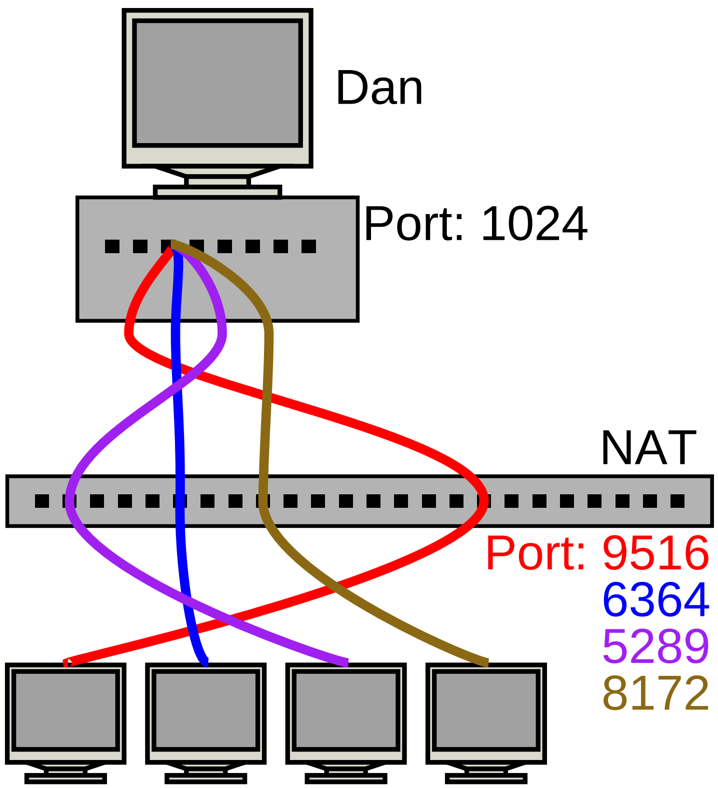

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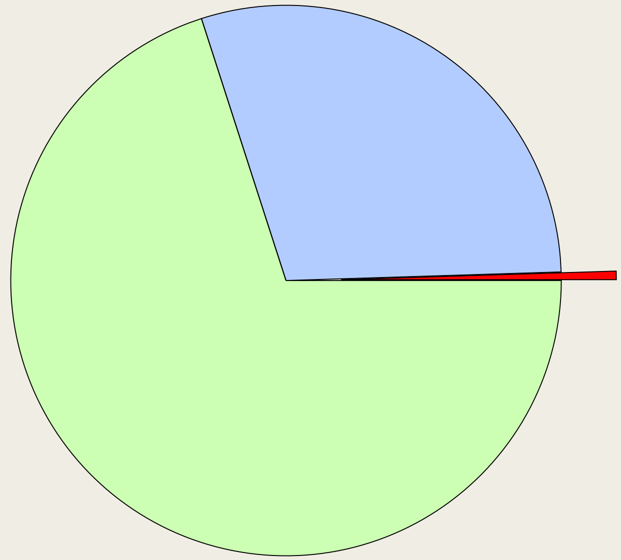
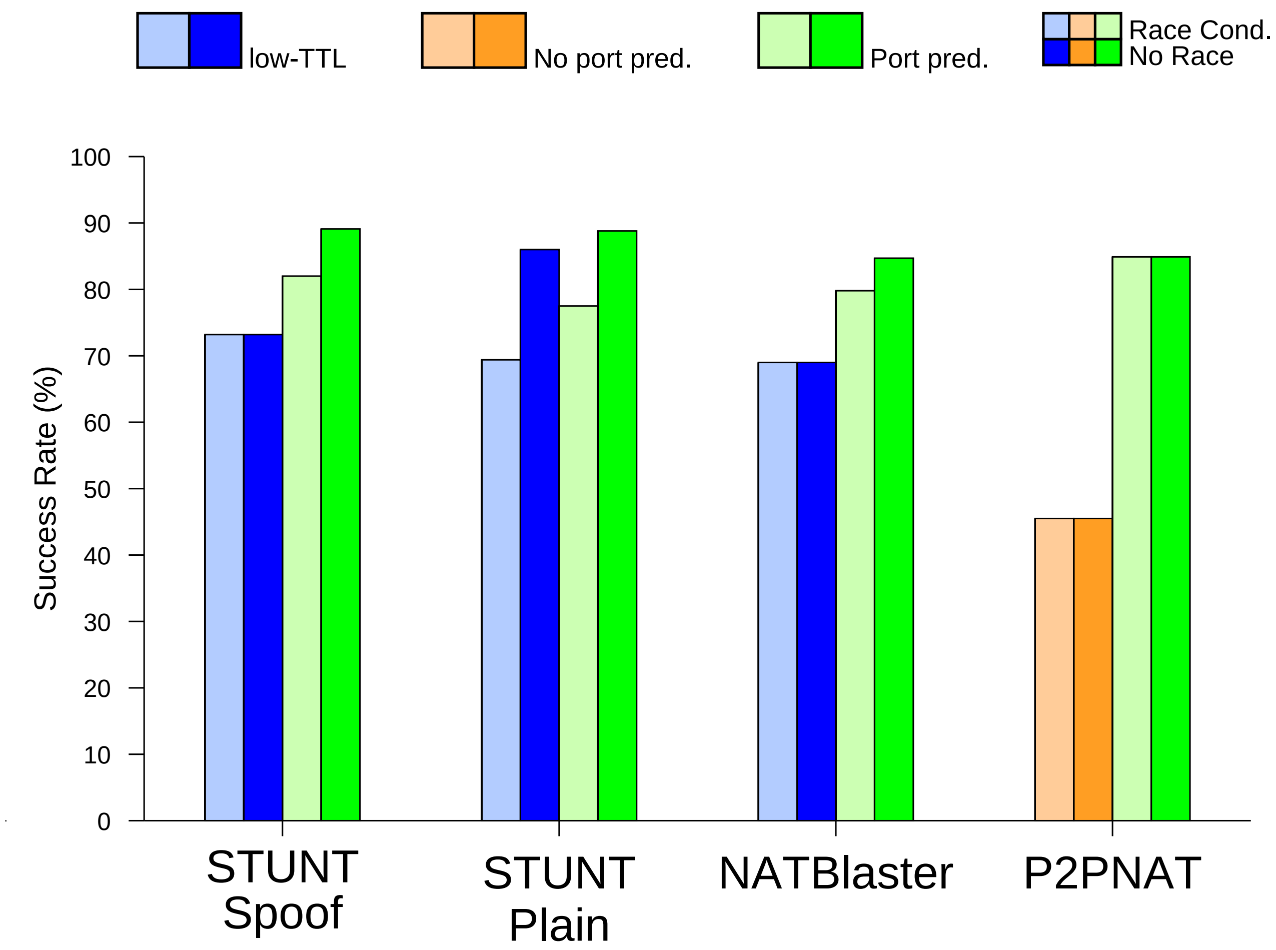


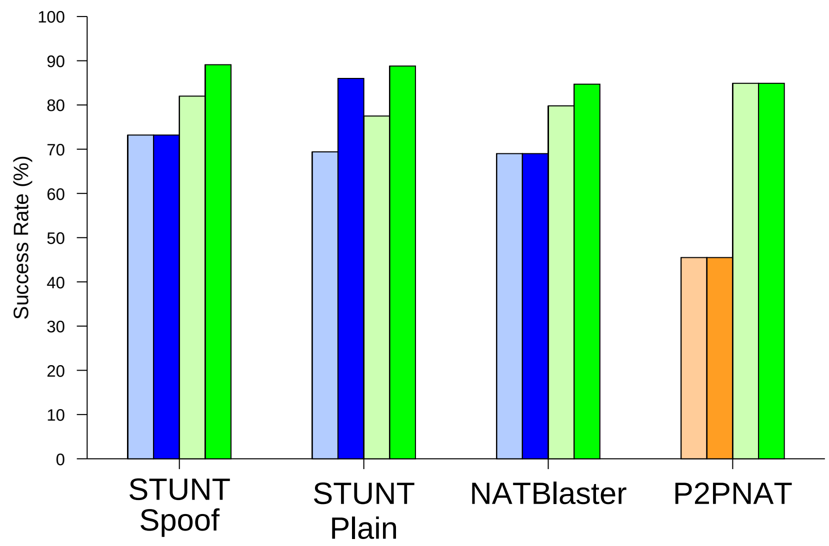
NB:Random

Projected Success



TCP traversal succeeds 85%-90% (estd.)

Projected Success



1. STUNT Spoof – Hard to deploy
2. STUNT Plain – Best Option
3. NATBlaster – Fails on WinXP SP2
4. P2PNAT – Fails on WinXP and earlier

Software

- NAT Traversal Library
  - JAVA implementation available
  - Encrypted tunnel application
- NAT Classification software
  - Windows, Linux versions available

Future Work

- Wide-scale testing
  - Implement in bittorrent, swarmcast, ...
- Standardize NAT TCP Behavior
  - IETF BEHAVE Working Group
  - I-D: draft-hoffman-behave

Related Issues

IPv6 . . .

- Transition will require v4–v6 NATs

Firewalls . . .

- Will persist even with IPv6

Universal Plug-and-Play (UPnP) . . .

- Off by default

Summary

- TCP NAT Traversal works!
  - 85%-90% today, 100% soon
- For P2P developers:
  - Application guidelines
  - TCP traversal library
- For NAT vendors:
  - Standards document
  - NAT checking software

`http://nutss.net/stunt`