Part 2:
Actual Internet Performance
Requirements and Constraints

Introduction to Networked Graphics

IEEE Virtual Reality 2011

Anthony Steed

- *Actual Internet Performance*
- - What bandwidth can we expect?
- - Sources of latency
- - What other issues must we consider?
- *Requirements and Constraints*
- - Requirements on consistency
- - Requirements on latency
- - User response to inconsistency and latency

Actual Internet Performance

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- - What bandwidth can we expect?
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Network properties

- Latency (Round Trip Time)
  - Devices take time to send data (e.g. Modems)
  - Data takes time to transmit (speed of light)
- Jitter
  - Routers insert bandwidth
- Bandwidth (Capacity)
  - Bandwidth costs money
  - In UK: 8Mbps is fairly standard @£10($15)/month
- Loss (Congestion, Reliability)
  - Routers drop packets, links do go down, routes do fluctuate

LATENCY & JITTER

Reality Check

GOLDEN RULE

Information propagation IS NOT instantaneous

It is not possible for EVERY user to share the EXACT same state at EVERY instance

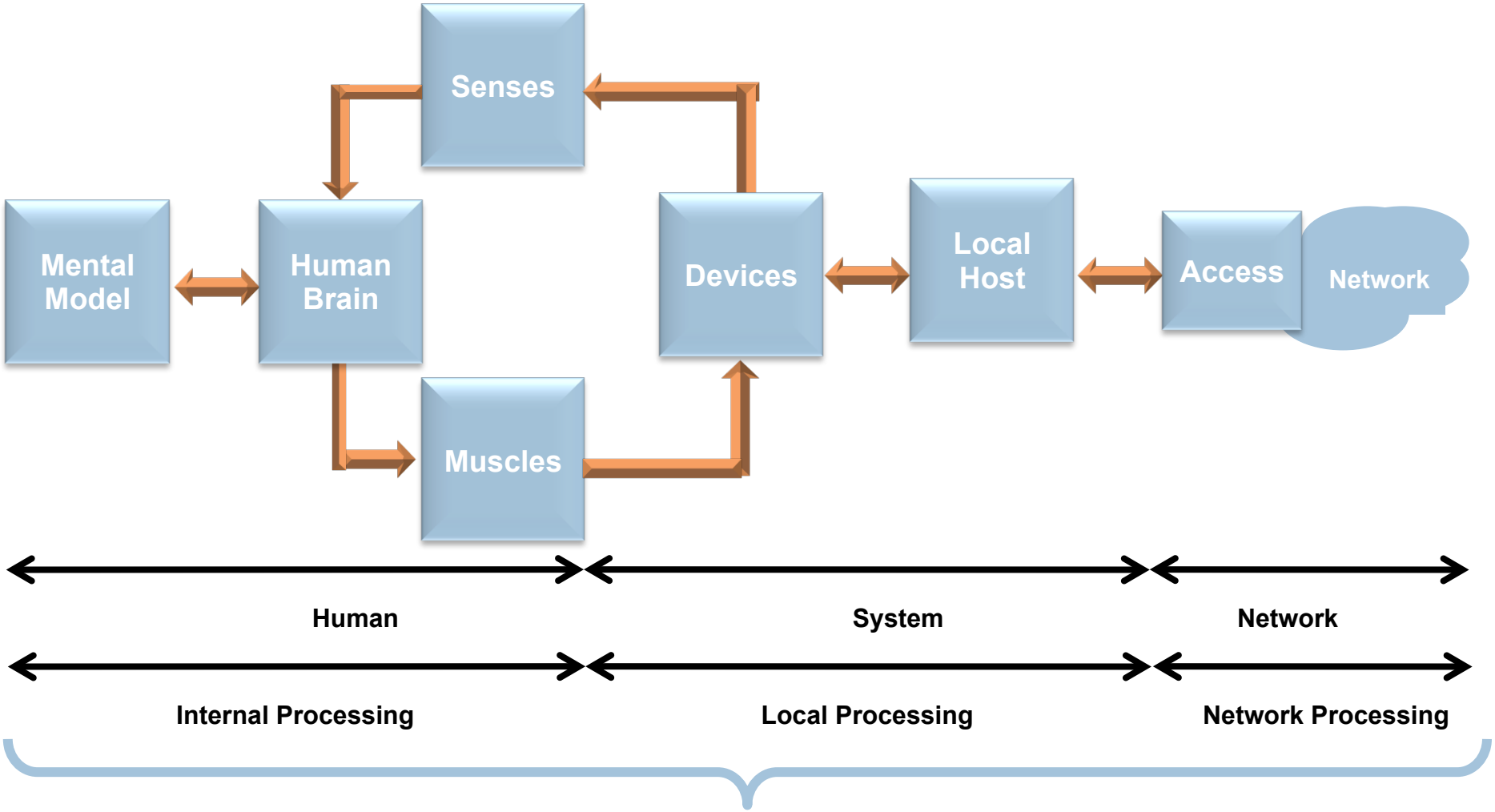
Impact on the Shared Experience

Host A

Host C

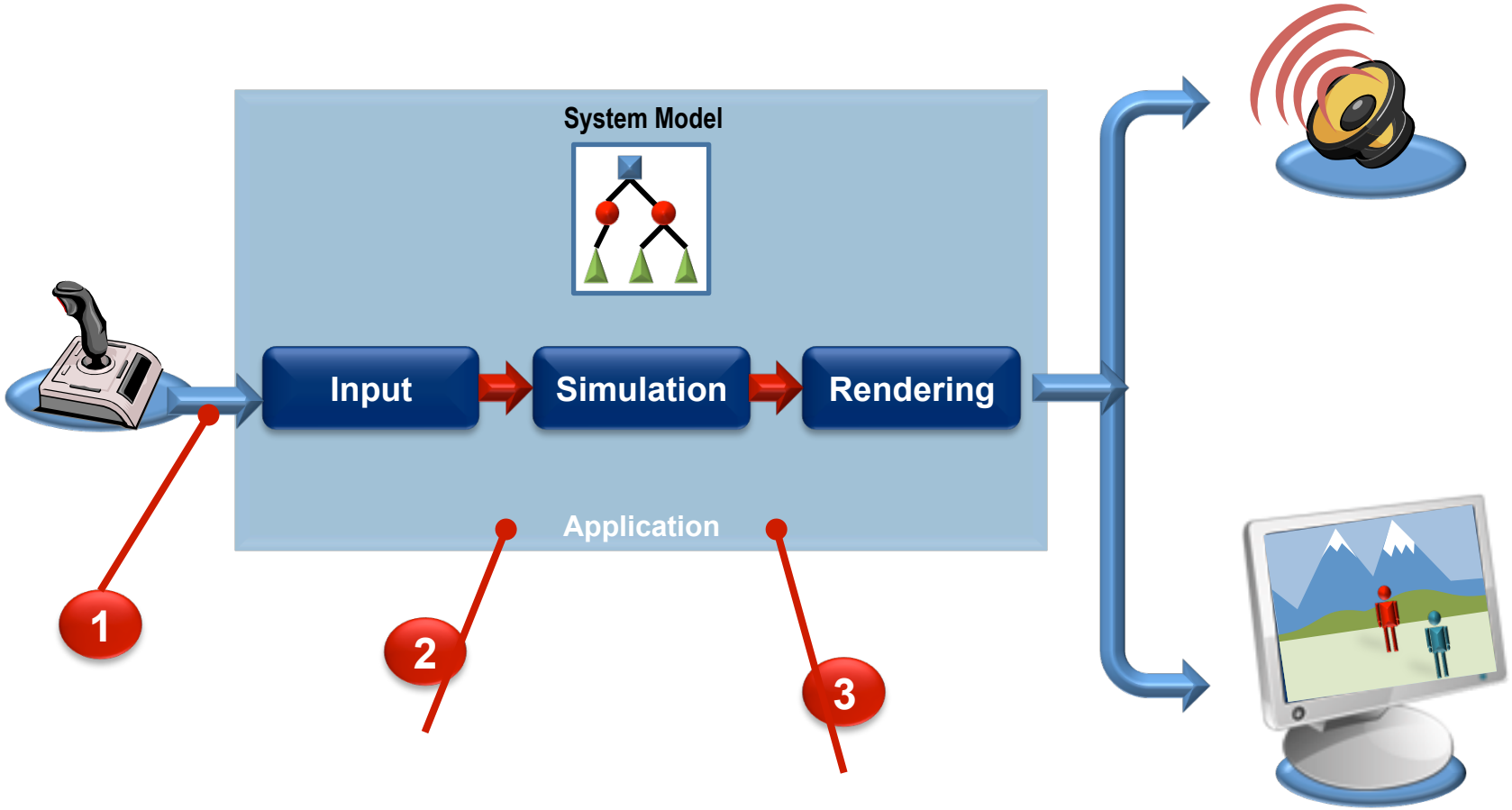
Host B

Overview of the Challenge

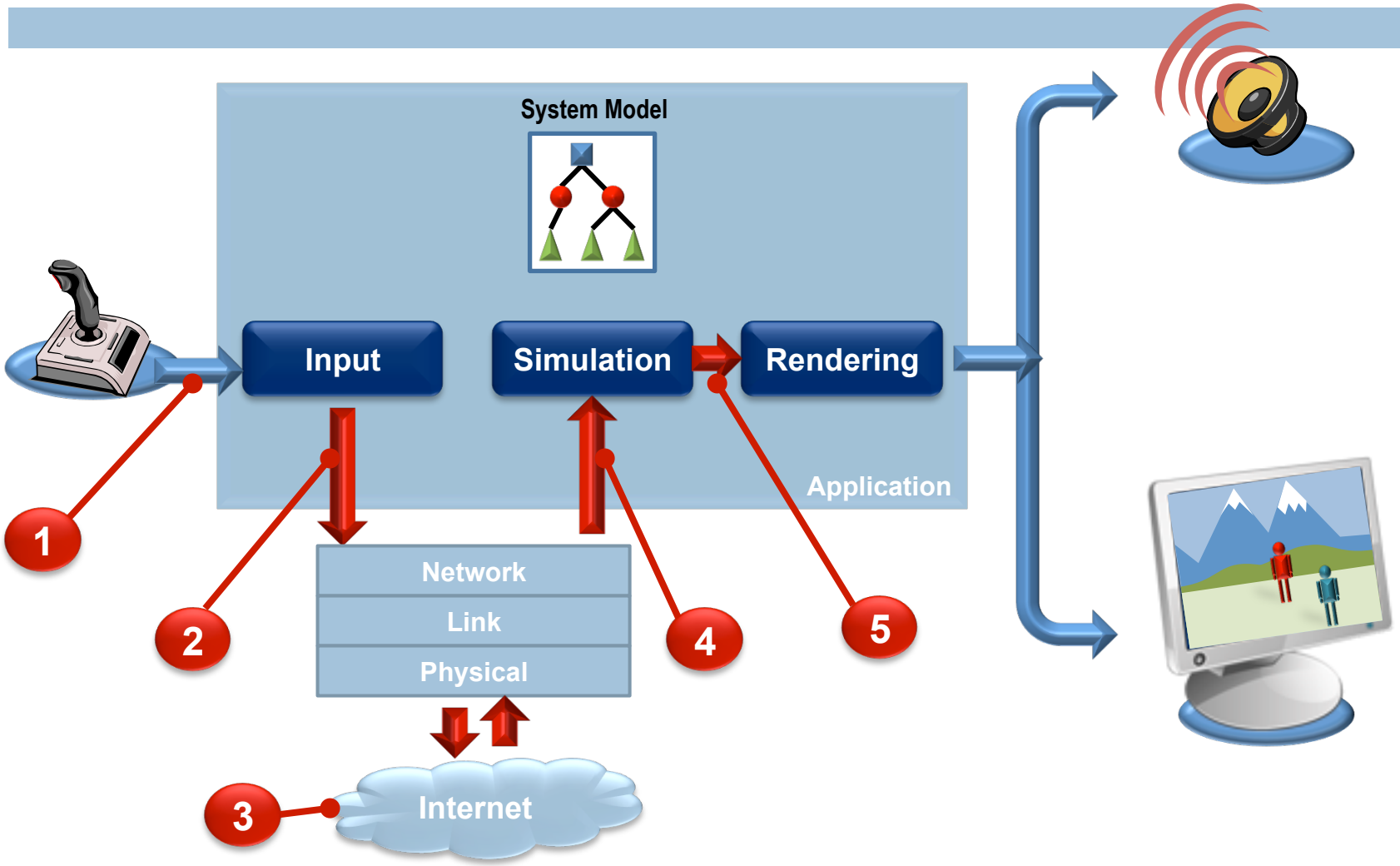


The total processing time must not exceed the interactive threshold which is determined by Gameplay

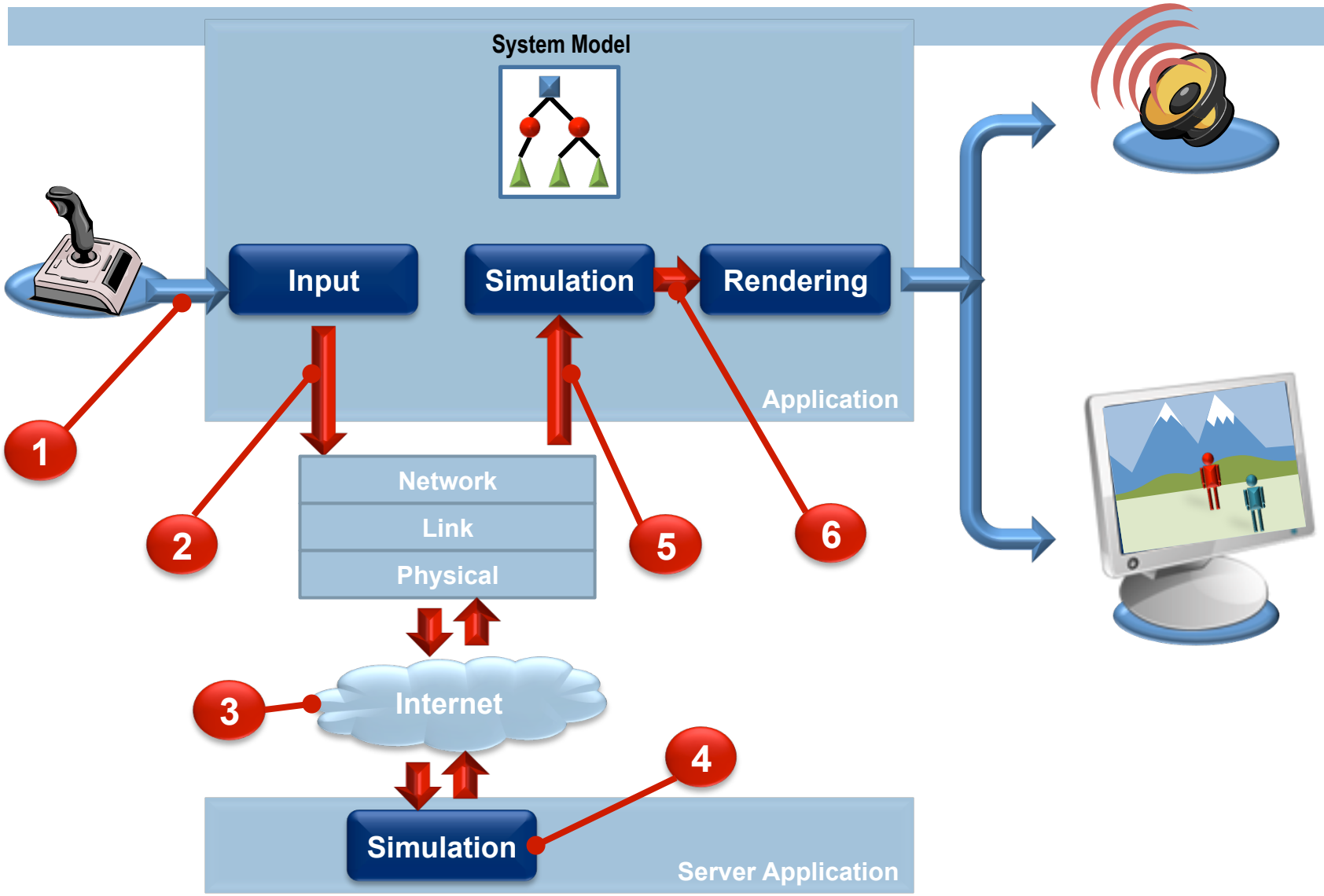
Latency and Jitter : Single Host



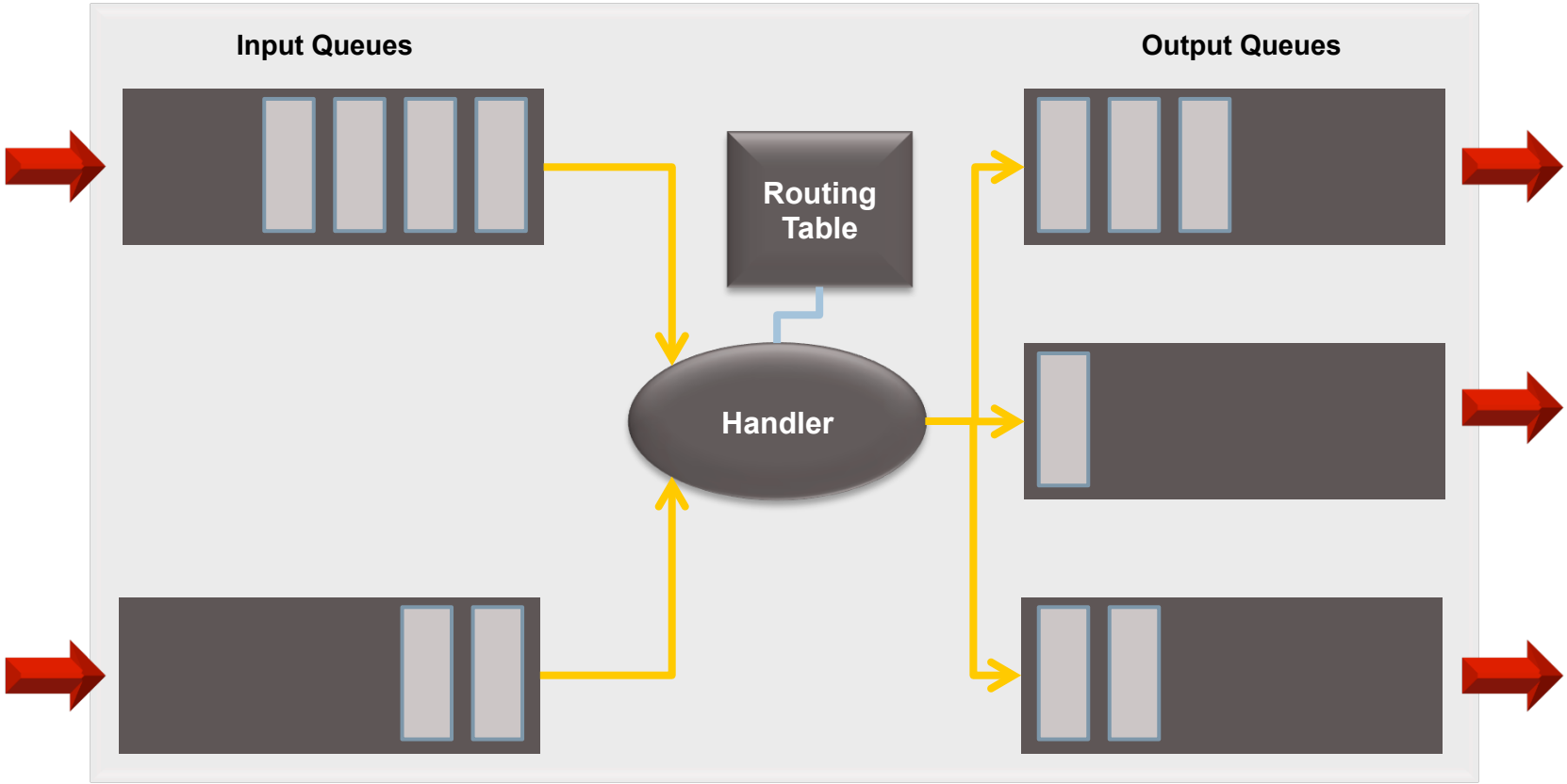
Latency and Jitter : Networked Host



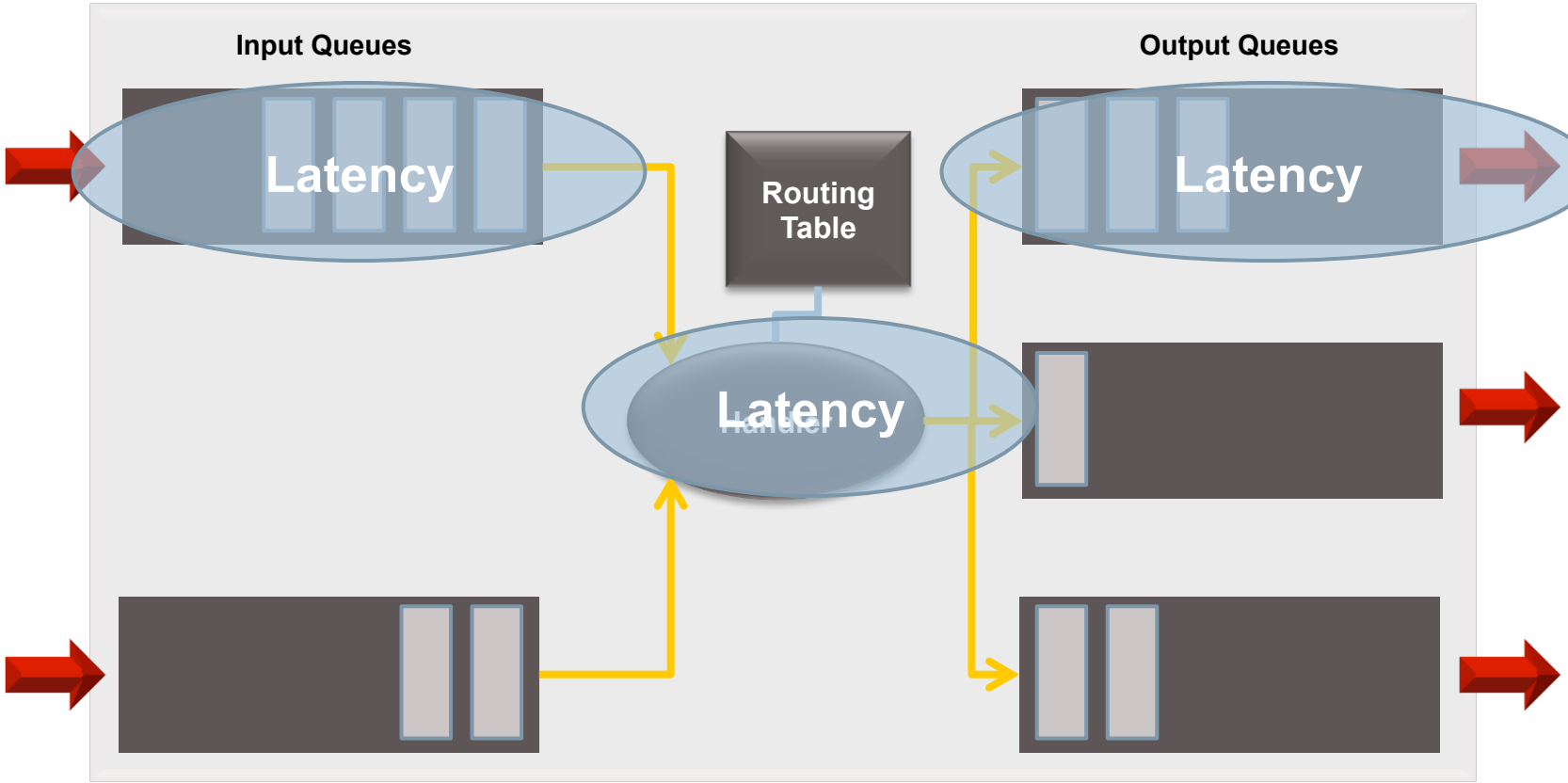
Latency and Jitter : Client and Server



Latency : Network Perspective



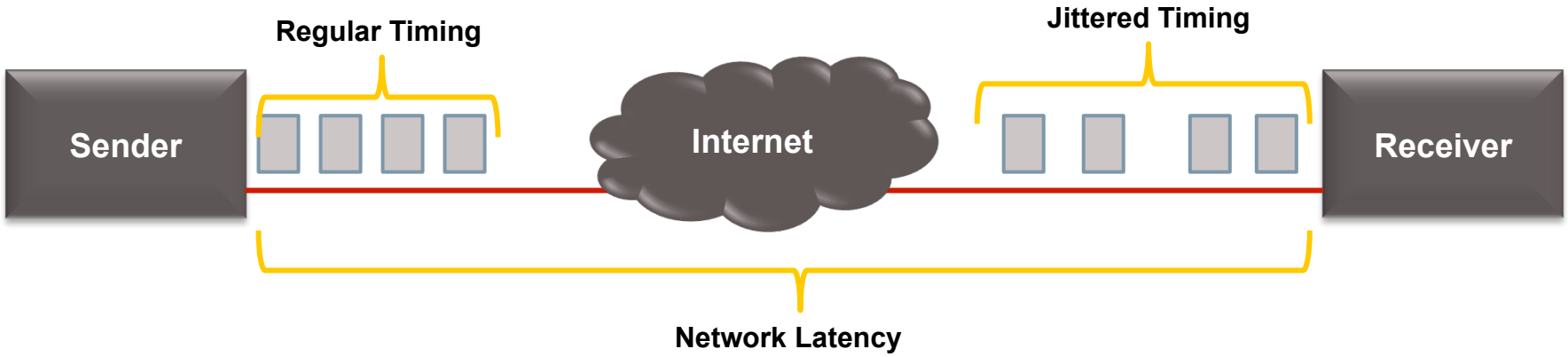
Latency : Network Perspective



Jitter

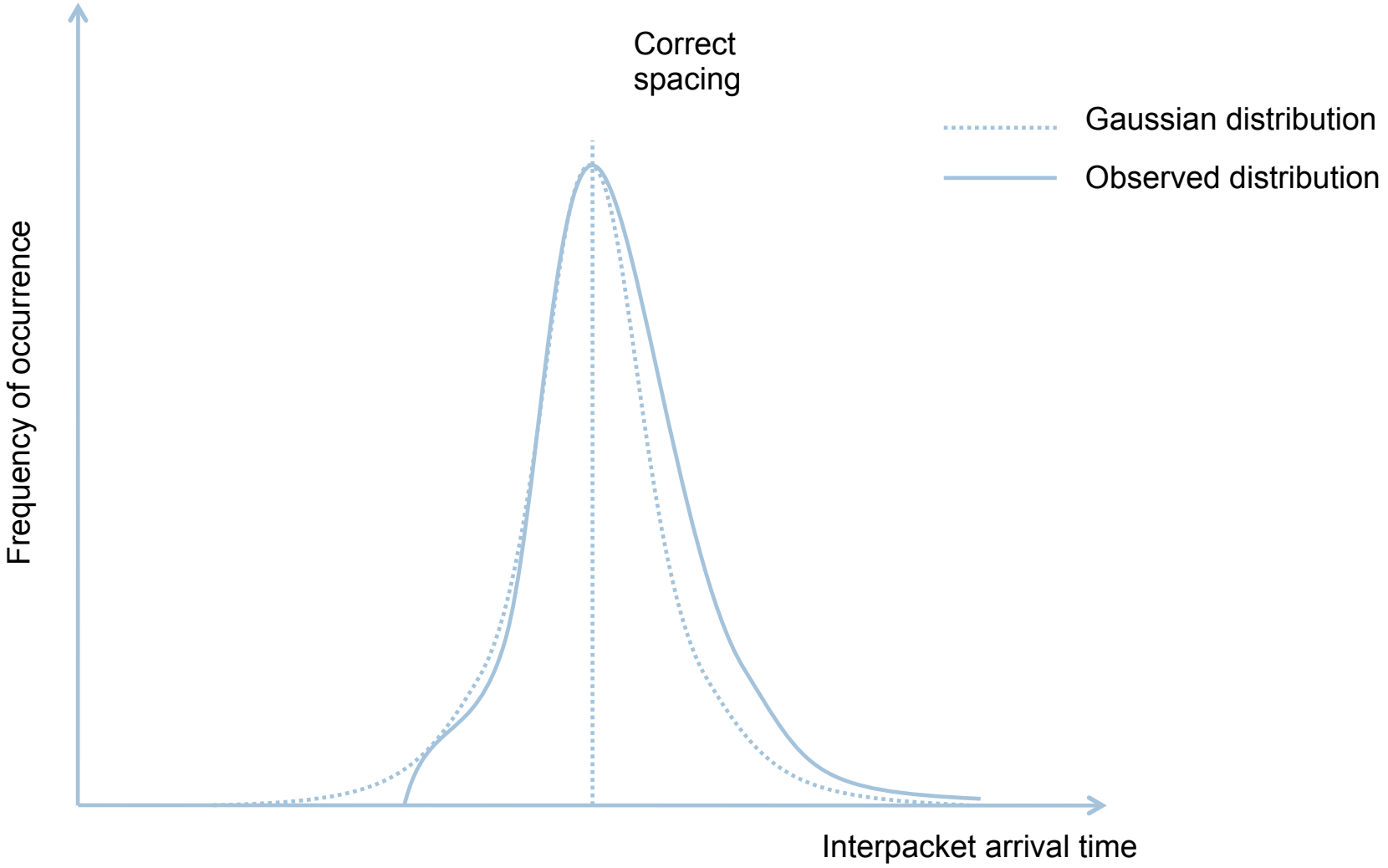
- Jitter is change in latency
- Jitter is caused by the technology of the Internet
  - Wired routers
  - Wireless access
- Two problems:
  - Routers are almost certainly capacity bound and demand on routers changes rapidly
  - Some link layers (notably wireless) are shared medium so transmitters will conflict

Latency and Jitter : Network Perspective



Transmission Delay : time it takes to put a packet on the outgoing link
Propagation Delay : time it takes for the packet to arrive at destination

Variance of inter-packet arrival times



BANDWIDTH & LOSS

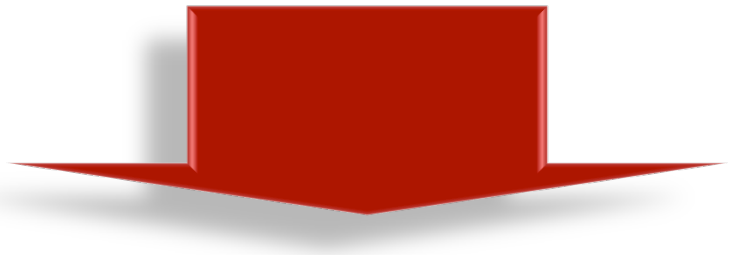
Bandwidth

- Bandwidth is a shared resource
- At local level we shared the wireless or share a home or office router
  - Can be much more outbound or requested inbound traffic that the local network can access
- However probably, the bottleneck is likely to be upstream to our ISP
- ISP have intra-ISP (and “senior” ISP) bottlenecks
- The destination site (BBC, Facebook) might have inbound capacity limits

Loss

Another GOLDEN RULE

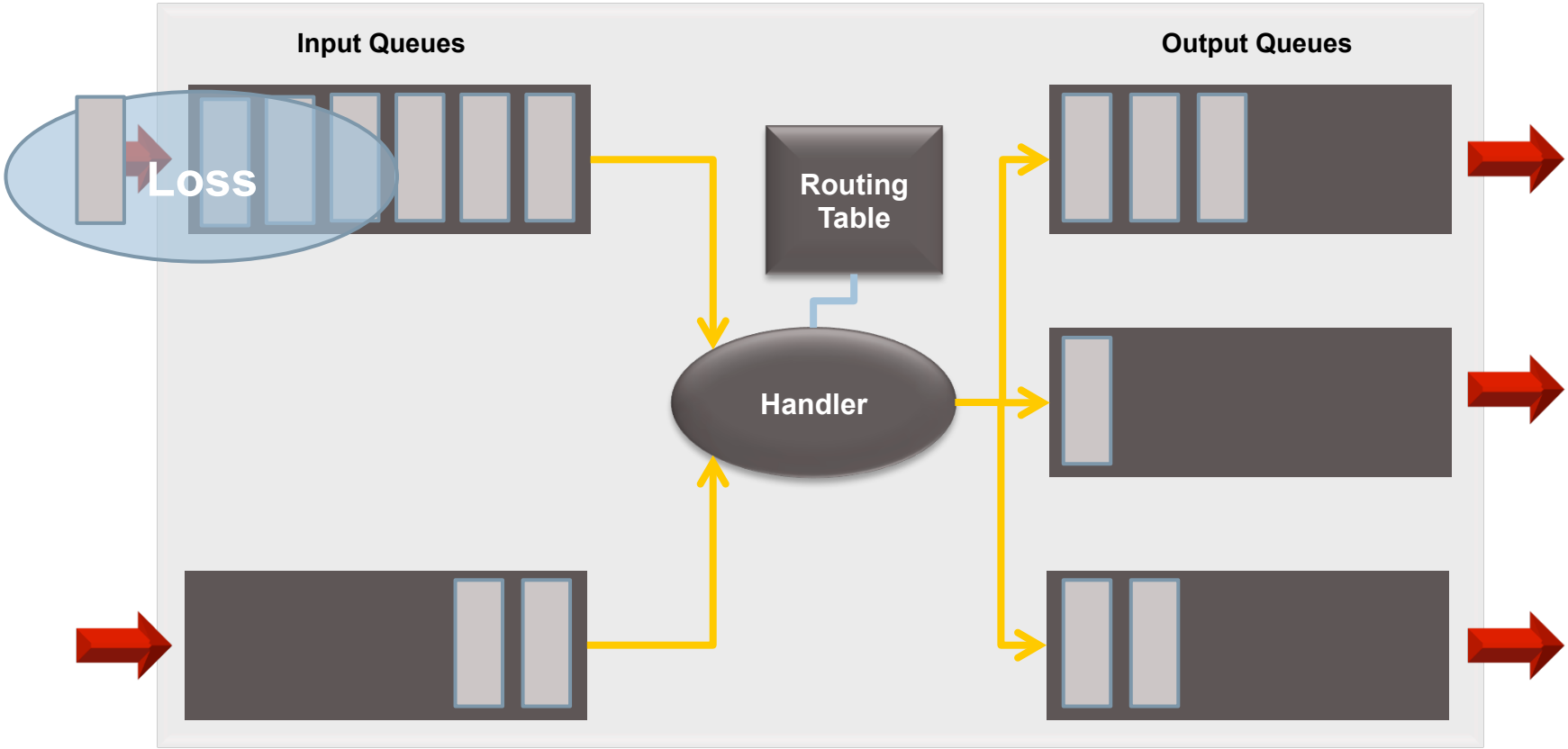
Packet Loss is a Good Thing



It is the Internet's defence against failure

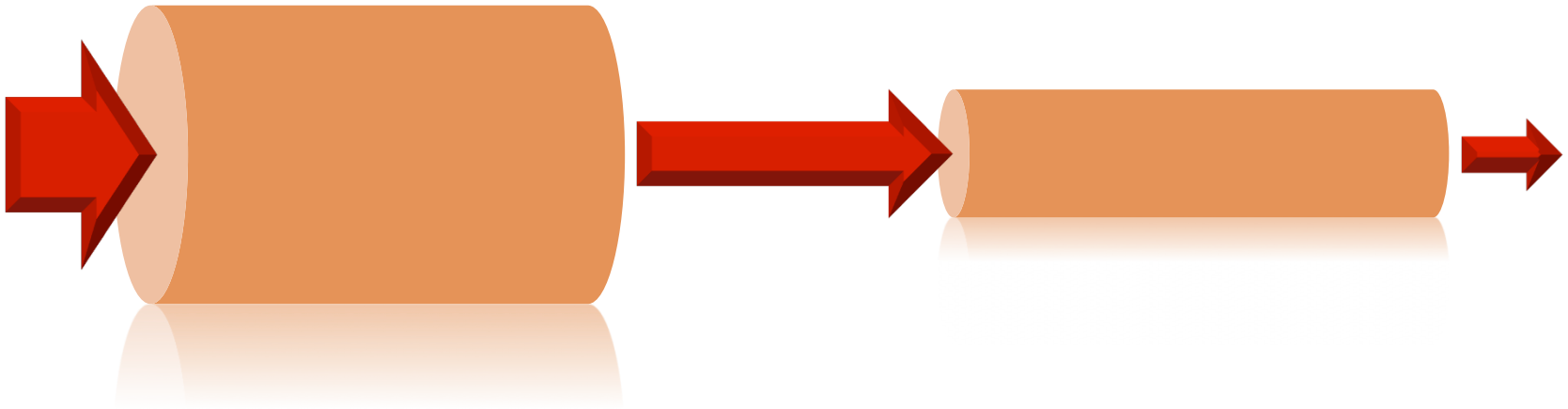
Dropping packets (hopefully) causes senders (processes or users) to rate-limit

Loss : Network Perspective



Throughput : Network Perspective

Throughput : number of bits per time of unit



Throughput : Network Perspective

Throughput : number of bits per time of unit

STATE OF THE INTERNET

Bandwidth and Latency: Wired

- Much literature in the area is based on 56kbps modems …
- Broadband is now common in homes
  - 500Kbps – 1Gbps
  - Depends on technology (twisted-pair v. optical)
- Offices have always been different
  - 1Gbps Ethernet, switched (not shared) is common
  - Outbound varies enormously
- Latency is good

Bandwidth and Latency: Wireless

- 2G
  - Don't try, run web or sms-based applications!
- 3G / 4G
  - 3G: ~2.4Mbps
  - 4G: 100Mbps – 1Gbps
- 802.11a-n
  - b: 11 Mbps
  - n: 54 Mbps
- Be skeptical: its shared bandwidth
- Latency is moderate-poor: its shared bandwidth

Bandwidth Availability

Rank	Country	Mbps Q4, 2008
-	Global	1.5
1	South Korea	15.0
2	Japan	7.0
3	Hong Kong	6.9
4	Romania	6.9
5	Sweden	5.6
6	Switzerland	5.1
7	Netherlands	4.9
8	Belgium	4.7
9	Slovakia	4.5
10	Norway	4.5
…		
17	United States	3.9

Average connection speed by country, Q4 2008. Based on (Akamai, 2009)

Effect of distance on throughput and download times

Distance from Server to User (miles)	Network Latency (ms)	Typical Packet Loss (%)	Throughput :Quality (Mbps)	4GB DVD Download Time
Local: <100	1.6	0.6	44:HDTV	12min
Regional: 500-1,000	16	0.7	4:Almost DVD	2.2hrs
Cross-continent ~3,000	48	1.0	1:Almost TV	8.2hrs
Multi-continent ~6,000	96	1.4	0.4:Poor	20hrs

Based on (Leighton, 2009)

Requirements and Constraints

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- *Requirements and Constraints*
- - Requirements on consistency
- - Requirements on latency
- - User response to inconsistency and latency

Consistency : System Perspective

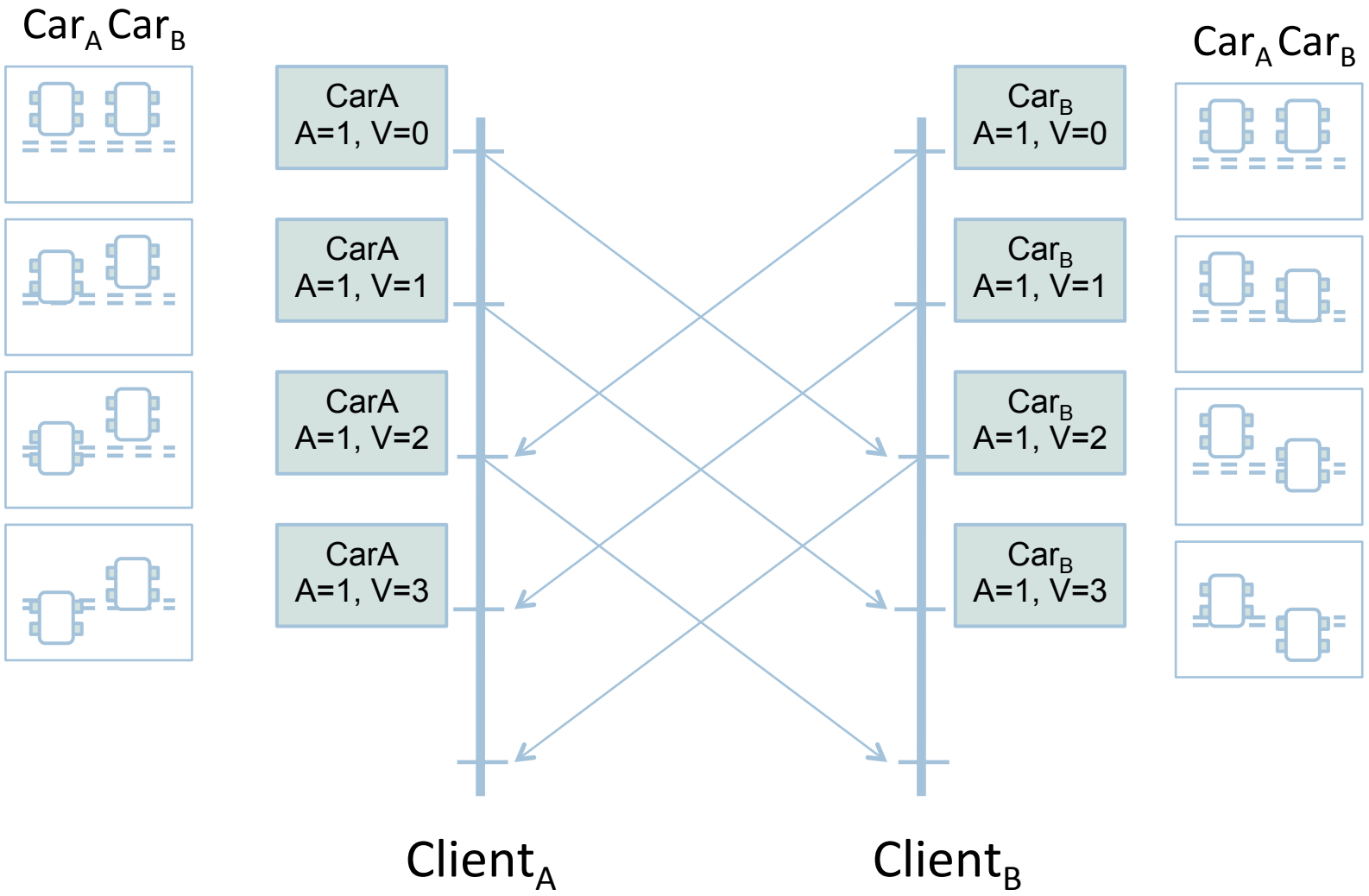
- C1 : Local changes replicated at each site
- C2 : Simulation should not diverge over time
- C3 : Casual order of events should be preserved
- C4 : Temporal and motion characteristics of events should be preserved

Consistency : User Perspective

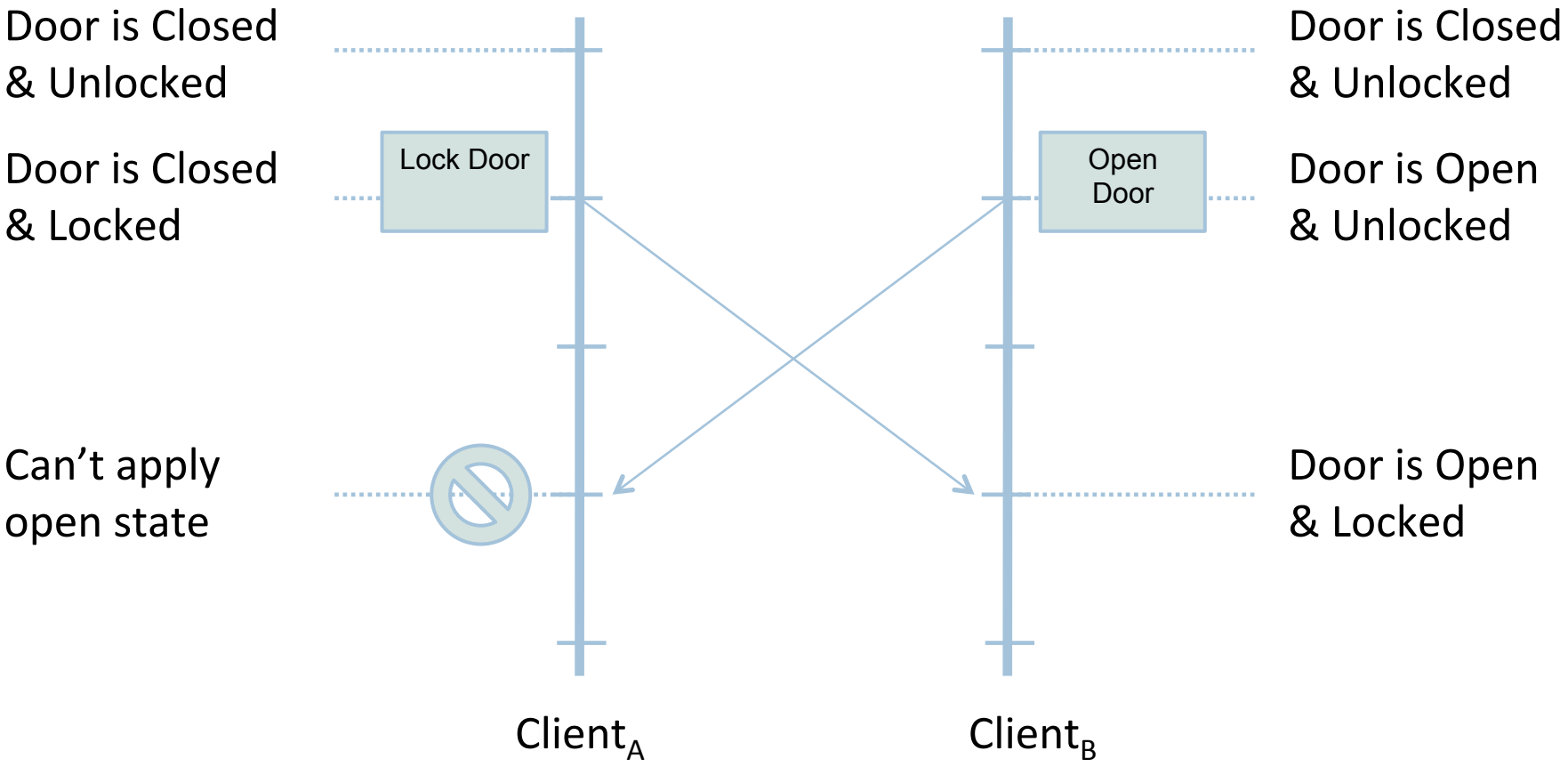
- C5 : The joint perception of events should be plausible
- C6 : The outcome of the events should be fair
- C7 : The system should preserve the users' intentions

LATENCY IMPACT

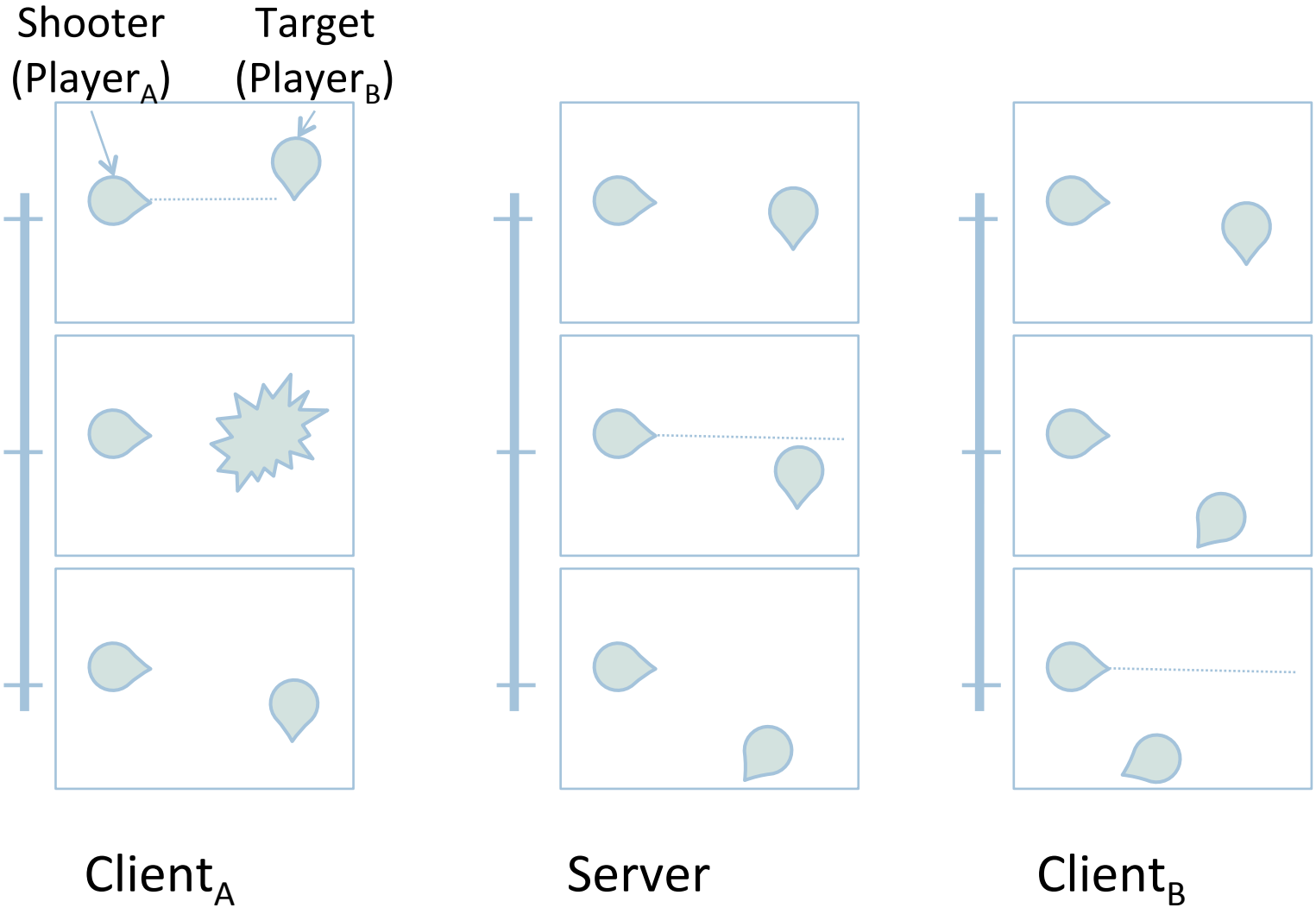
Impact: Timings Activity Onset



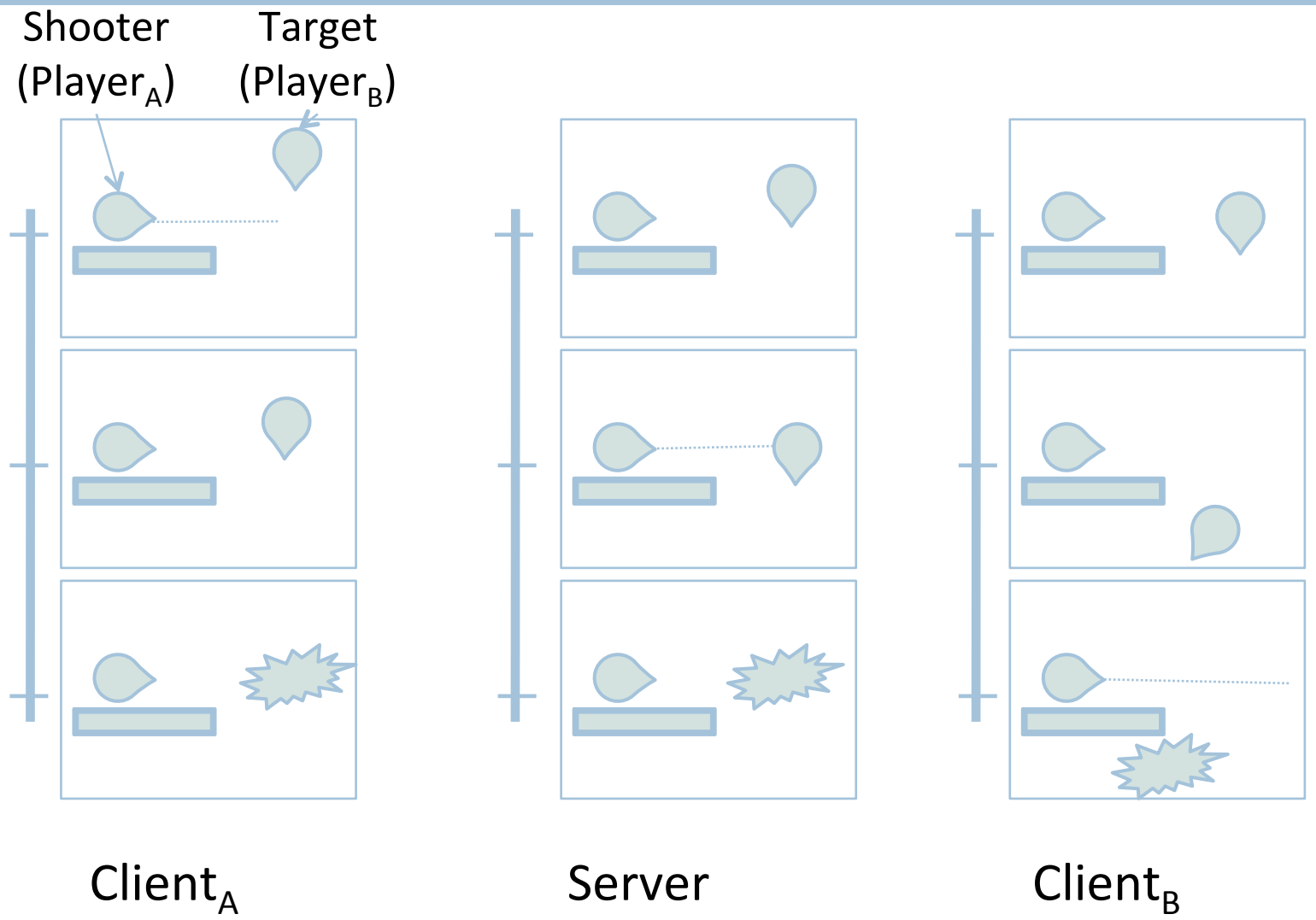
Impact: Inconsistent State Changes



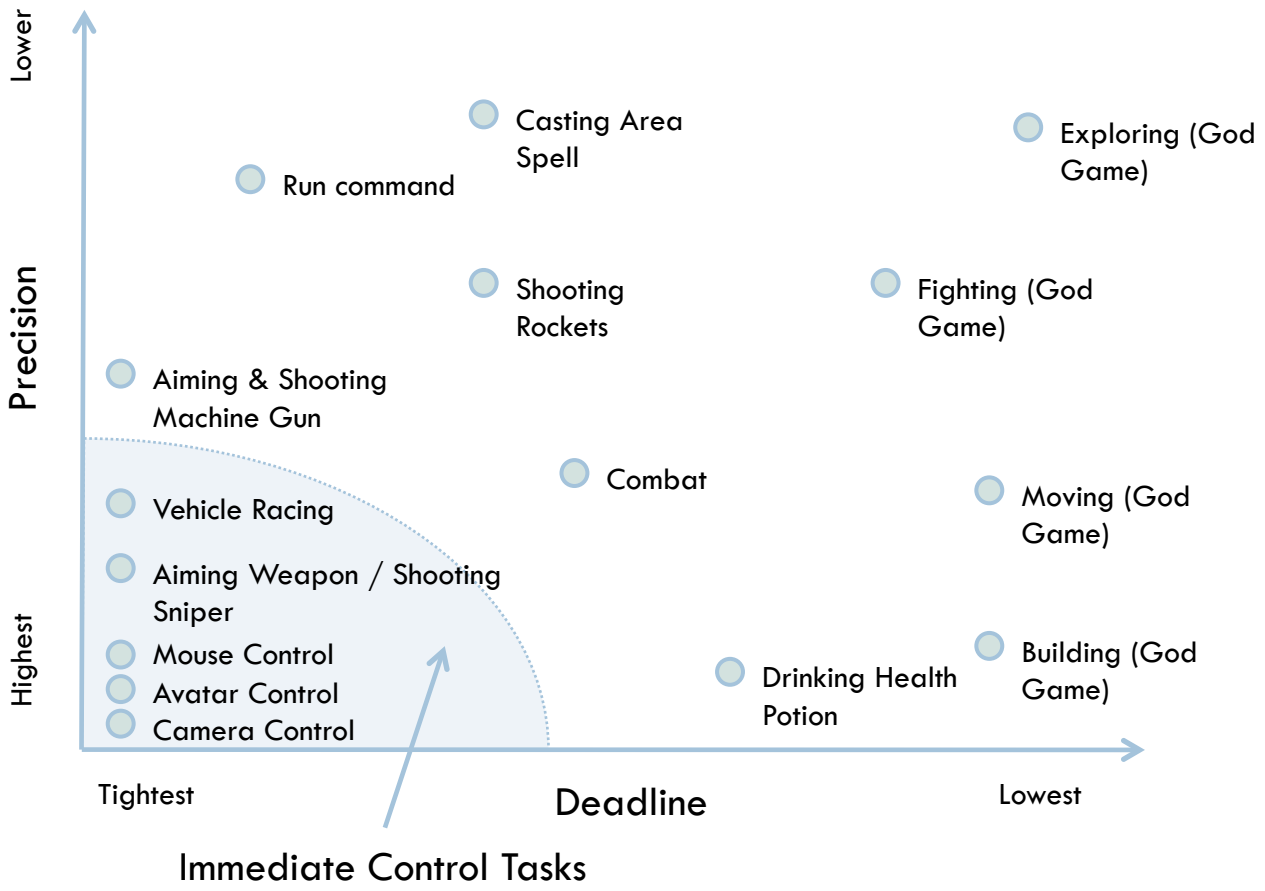
Impact: Fireproof Players



Impact: Shooting Around Corners



Latency Acceptability



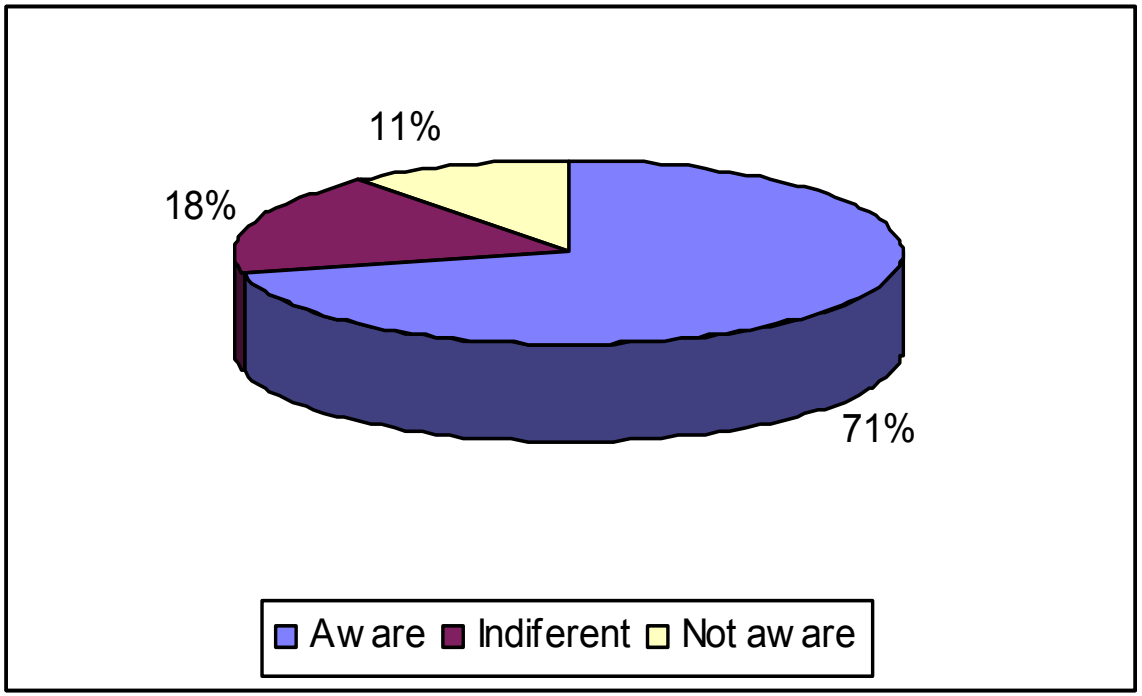
Several tasks plotted on the Precision/Deadline axes. Based on Claypool and Claypool (2006).

What Do Users Think? (1/4)

- Online survey targeted at First Person Shooter (FPS)
- 23 Questions with 7 scale Likert response
- 335 unique responses
- Sample is non-casual players
  - 75% have more than one year experience
  - Average weekly hours playing is 5-10
  - 68% buy hardware depending on game (indecisive 16%)
  - 73% consider themselves proficient players (indecisive 16%)

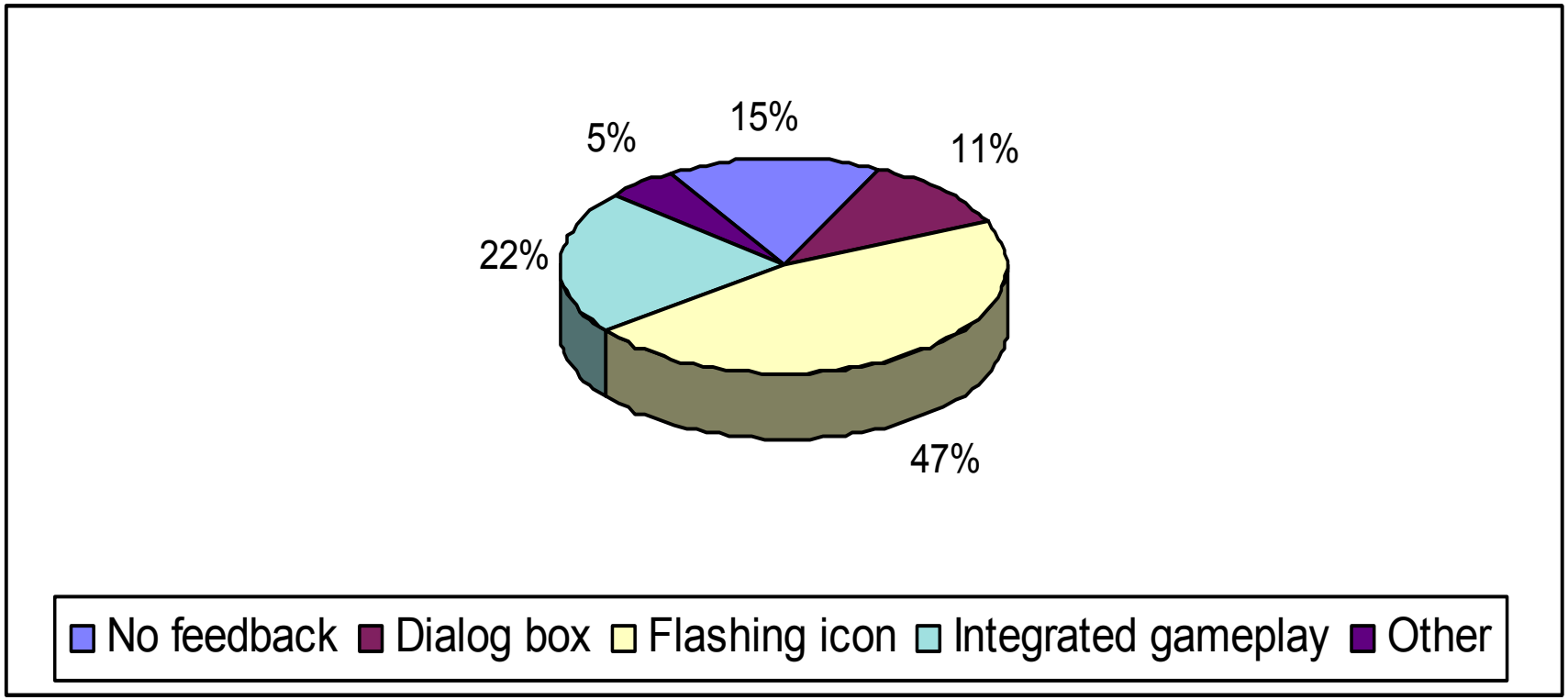
What Do Users Think? (2/4)

Are users aware of network problems?



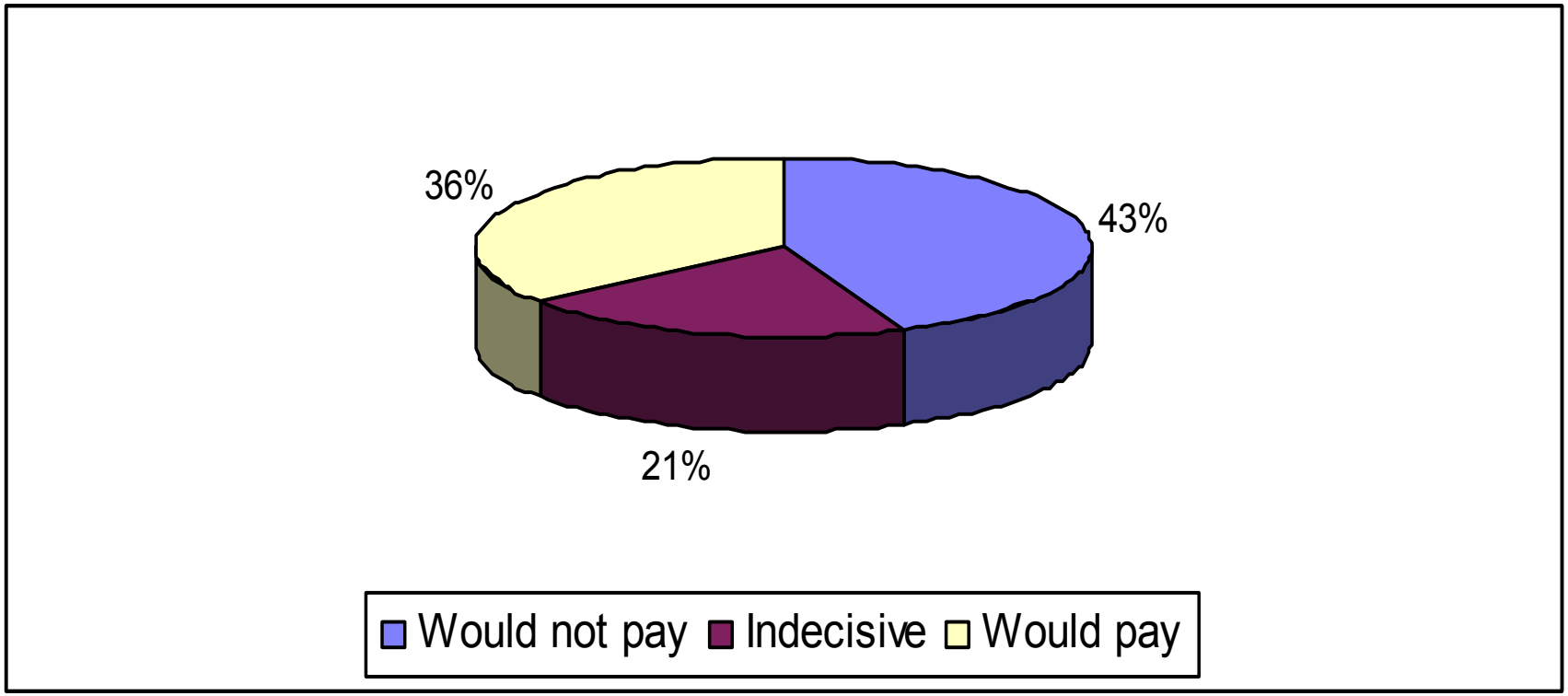
What Do Users Think? (3/4)

Users want to know what is going on…



What Do Users Think? (4/4)

Users want QoS but…



BANDWIDTH

Bandwidth Requirements

- Obviously depends on activity
  - Downloading models
  - Sending small, game specific commands
  - Rate of command sending (very sensitive to type of game)
- Typically:
  - FPS & real-time send commands at fixed rate (e.g. 20 Hz)
  - RTS and other send commands at issue rate (e.g. up to 5Hz with StarCraft)

Packet Rates

Game	Packet Rate In (pps)	Packet Rate Out (pps)	Packet Size In (bits)	Packet Size Out (bits)
Day of Defeat	421.85	341.92	41.73	162.78
Medal of Honor: Allied Assault	379.67	294.10	50.10	291.71
Unreal Tournament 2003	469.89	123.43	27.92	117.74

Server packet rates and sizes for three FPS games, from Feng et al. (2005)

Packet Rates

Game	Packet Rate In (pps)	Packet Rate Out (pps)	Packet Size In (bytes)	Packet Size Out (bytes)
World of Warcraft	6.39	6.21	220.25	71.12
Guild Wars	3.76	3.83	183.19	57.78
Eve Online	0.84	0.86	261.18	64.41
Star Wars Galaxies	12.26	6.34	156.47	77.25

Client packet rates and sizes for four MMORPG games, from Molnár & Szabó (2008)

Packet Rates

Zone Type	Direction	Standing (kbps)	Walking (kbps)	Teleport (kbps)	Flying (kbps)
Dense & Crowded	S-C	192	703	1164	877
	C-S	15	31	33	31
Dense & Deserted	S-C	141	278	445	821
	C-S	30	46	36	52
Sparse & Deserted	S-C	10	31	448	27
	C-S	13	74	36	73

Bandwidth of Second Life for different region types and different modes of travel. From Kinicki & Claypool (2008)

CONNECTIVITY

Network Address Translation

- The biggest hiccup for any peer to peer networking
- Many (most?) computers on the Internet are behind a NAT
- We are behind a NAT
  - 192.168.14.32 is in a *reserved* IP address domain
- Your home probably runs a NAT
  - You have one address from your ISP
  - You PAY to have this be a static IP address
  - You pay more to have more than one

Reserved Addresses

IANA-reserved private IPv4 network ranges

	Start	End	No. of addresses
24-bit Block (/8 prefix, 1 × A)	10.0.0.0	10.255.255.255	16 777 216
20-bit Block (/12 prefix, 16 × B)	172.16.0.0	172.31.255.255	1 048 576
16-bit Block (/16 prefix, 256 × C)	192.168.0.0	192.168.255.255	65 536

IP address. (2011, March 18). In Wikipedia, The Free Encyclopedia. Retrieved 07:24, March 19, 2011, from http://en.wikipedia.org/w/index.php?title=IP_address&oldid=419473743

What Does NAT Do?

- Network Address Translation is a function of your router (gateway)
- You have any number of devices on your LAN
- All appear to have the same IP to the outside world
- The NAT replaces the source *address* and *source port* of the IP packets

What a NAT Does

- Store a table

Outward Port	Inward Address	Inward Port
80	192.168.1.2	80
8080	192.168.1.3	80
7123	192.168.1.2	7123

- Not trivial to do this, some systems use lots of connections and ports
  - Overload is a common cause of WLAN falling over

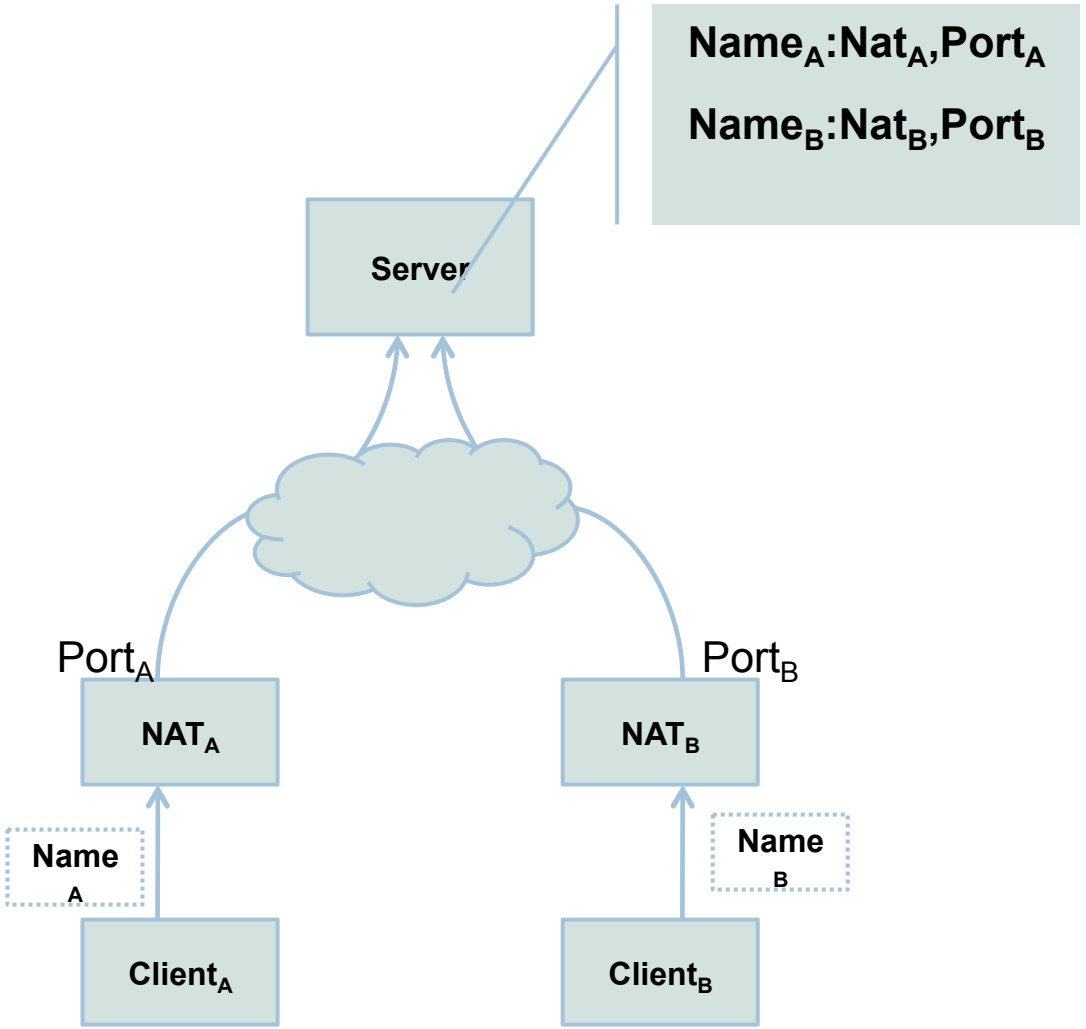
Implication of NATs

- There is no problem calling out
- Calling in you can't know automatically which machine behind a NAT uses what ports
  - The NAT needs to discover or be told that port 80 (web service) packets need to be routed to a specific machine
  - Most home gateways have functionality for this specifically for running game services!
- This is a problem for any peer to peer system. Your likely experience with it is using Skype

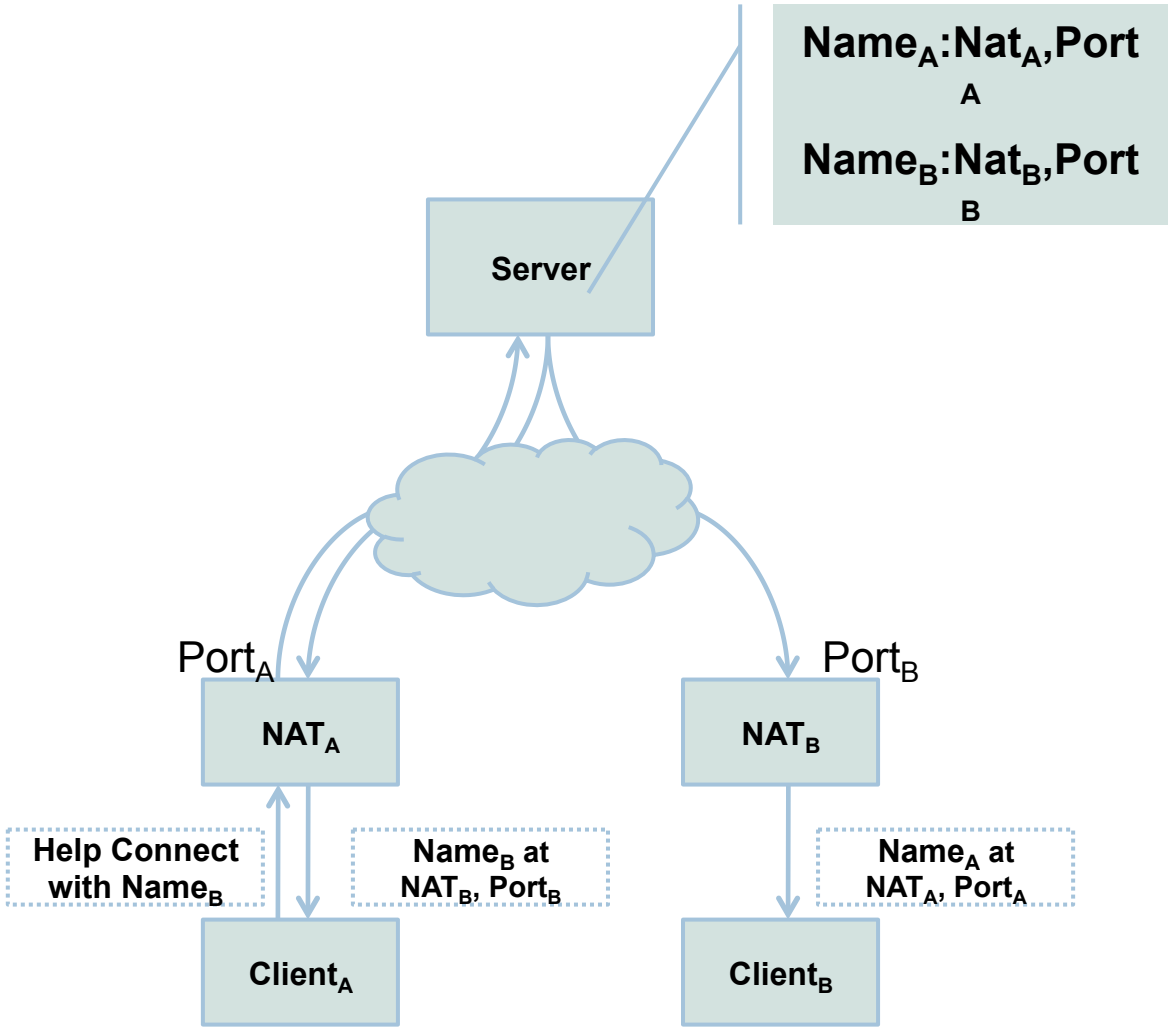
NAT Traversal

- NAT breaks one of the fundamental assumption of Internet: that all machines are peers and are routable by IP number
- NAT traversal is supported by some protocols
  - E.G. callback: protocol can work in either way, TCP is also bidirectional
- Otherwise need to do it yourself

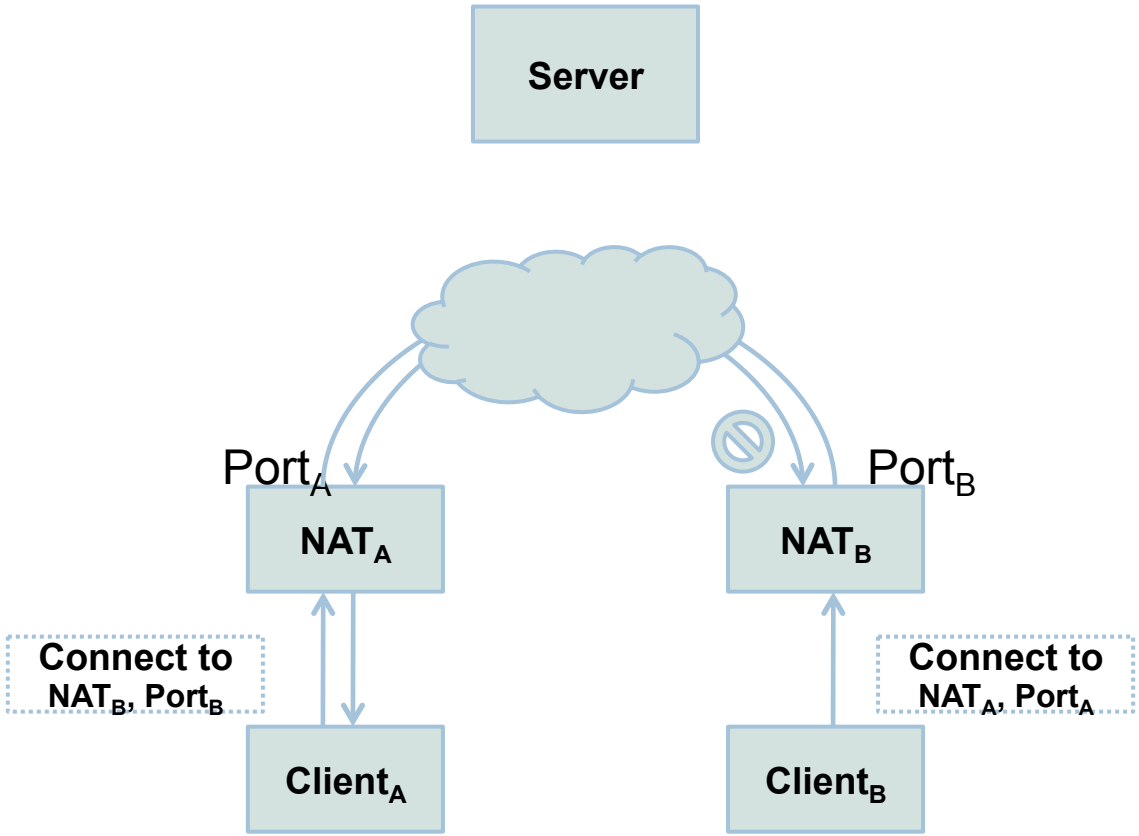
UDP Hole Punching



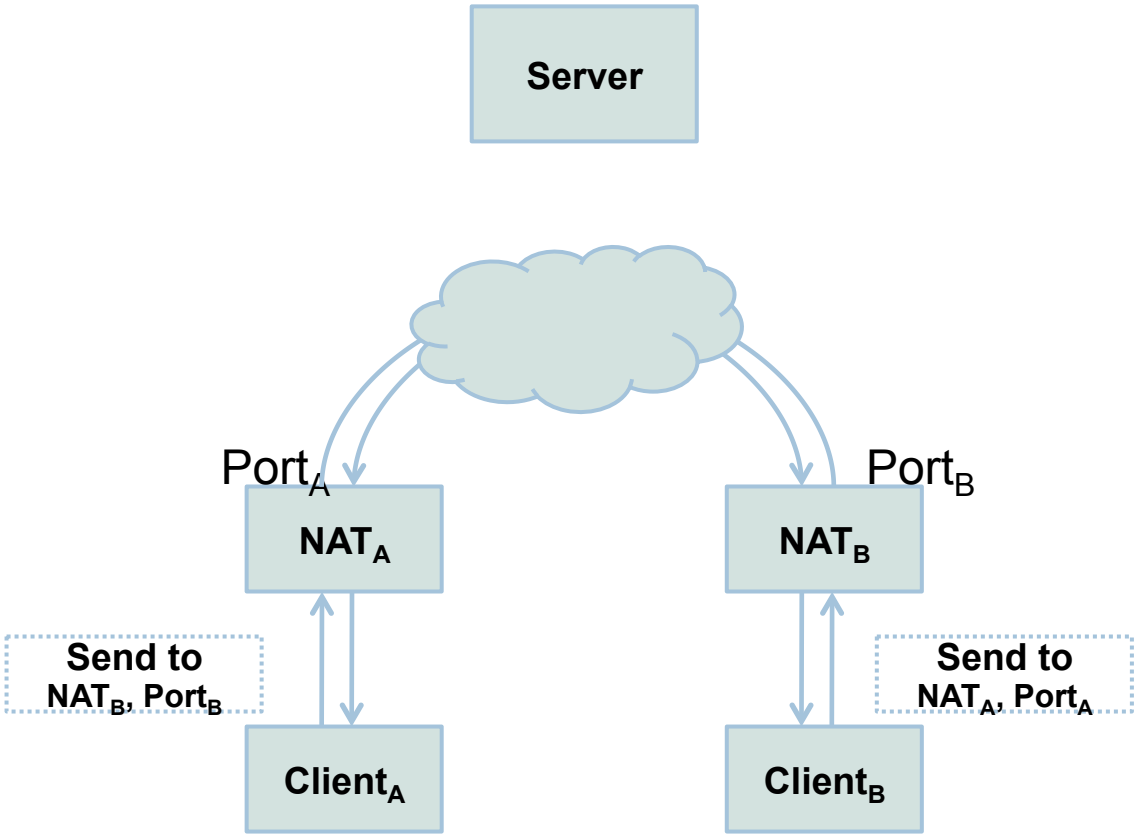
UDP Hole Punching



UDP Hole Punching



UDP Hole Punching



Comments on NATs

- Many types of NAT, port static, symmetric, etc.
- UDP Hole Punching only works some of the time
- There is an equivalent for TCP which is less reliable!
- Many game middleware have a function for this
  BUT
  - Game providers need to provide a rendezvous service
  - Need a relay service when it fails
- For a peer to peer game, middleware tries to assess which client has best connectivity

Firewalls

- Firewall blocks incoming and outgoing traffic
- Firewall is often combined with NAT
- Block ports
- Block addresses
- Block protocols (depending on state of connection)

SUMMARY

- Today bandwidth is growing rapidly
- NVEs and NGs tend to demand a lot from the network
  - Some games have low latency requirements
  - Packet rates vary enormously
- The Internet is actually poorly symmetrically connected

- Part 3 will look at techniques to cope with latency and scale