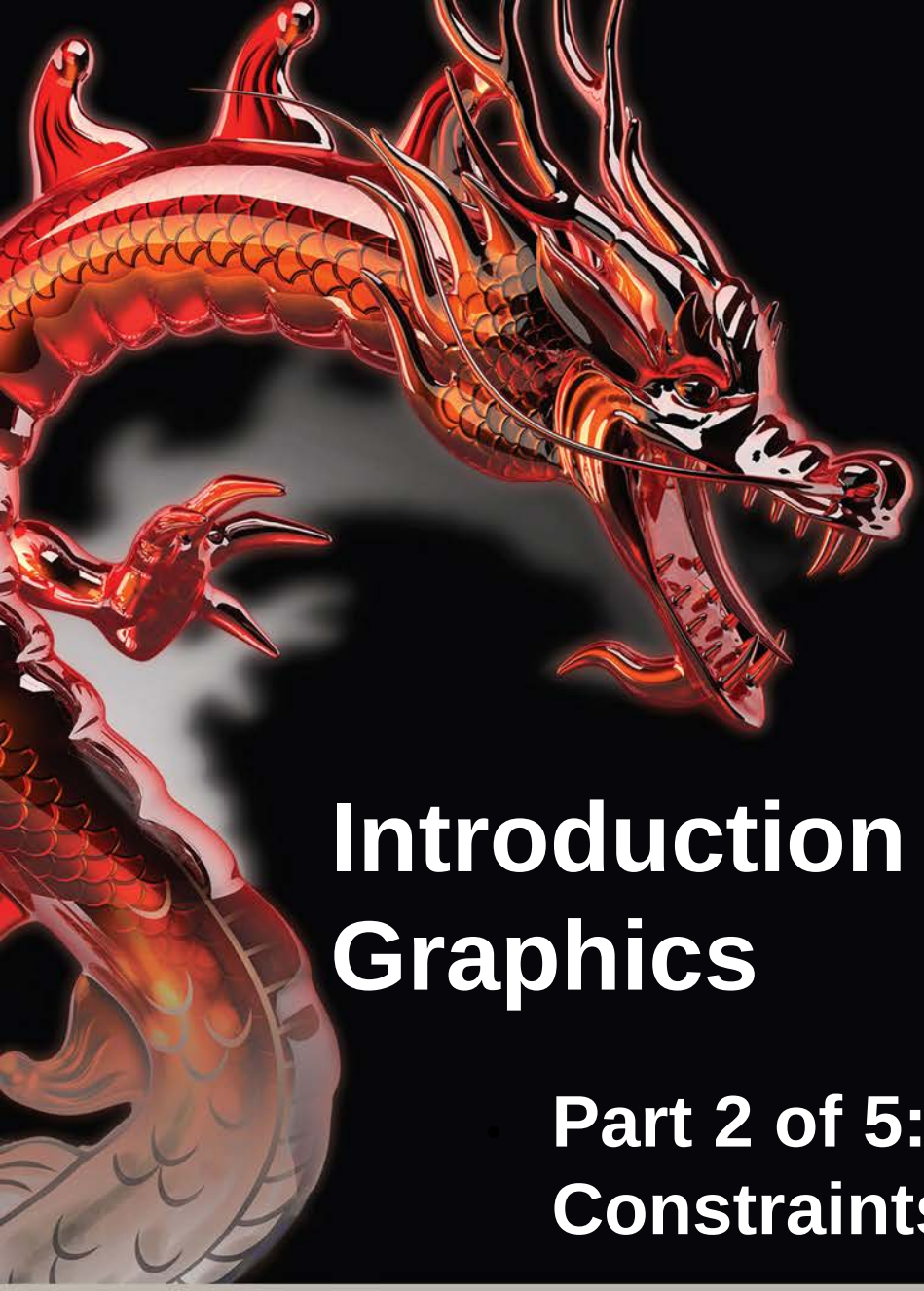


Introduction to Networked Graphics

Part 2 of 5: Requirements and Constraints

Overview

- Goal:
  - To give an overview of the performance of the Internet and how it affects how NVEs can work.

- Topics:
  - Internet performance
  - Why are all types of networked graphics non-standard networking applications?
  - Requirements on consistency
  - Implications for latency and scalability

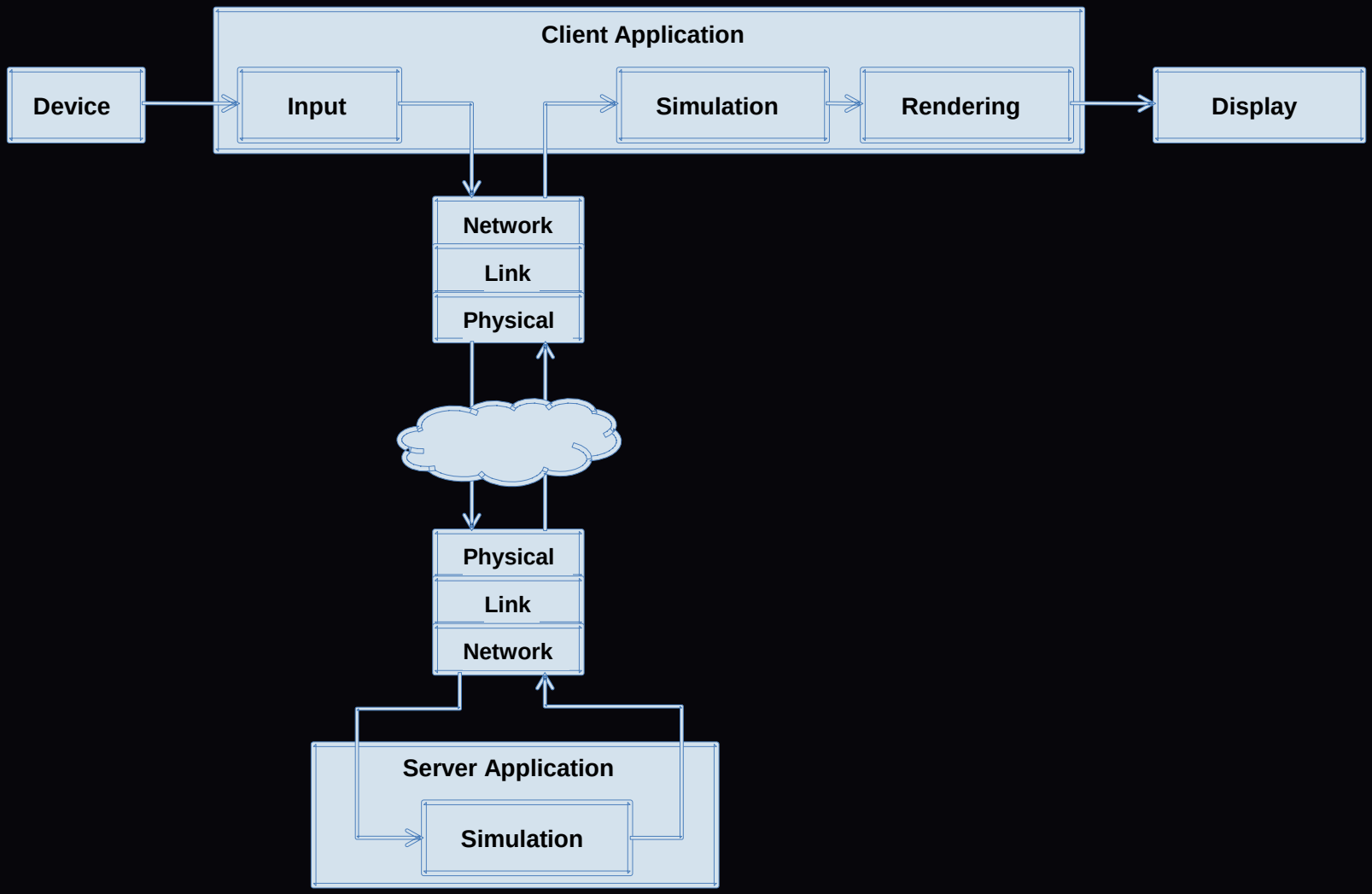
Internet performance

- Latency (Round Trip Time)
  - Time to transmit data (speed of light, modems)
- Jitter
  - Routers insert bandwidth
- Bandwidth (Capacity)
  - Broadband for WAN, Ethernet for LAN?
- Loss (Congestion, Reliability)
  - Routers drop packets, links do go down
- Not fully connected
  - Network address translation

Latency

- Sources of latency
  - Speed of copying to link (e.g. modem)
  - Speed of transmission in link (e.g. speed of light)
  - Client scheduling (when packets arrive compared to the commitment to render the effect)
  - Server scheduling (e.g. server updates at a fixed frequency)

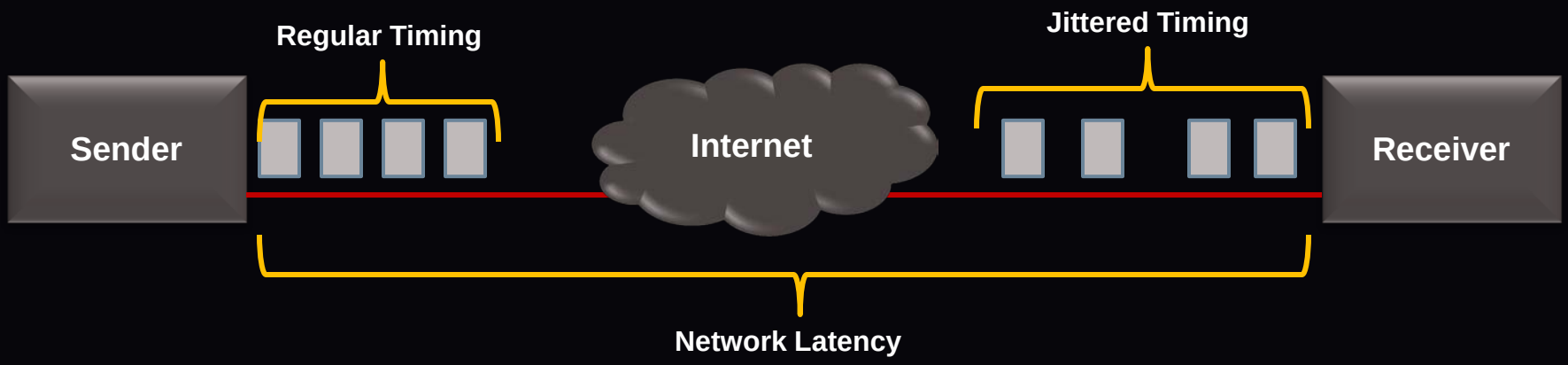
Latency


Client Application
Device
Input
Simulation
Rendering
Display
Network
Link
Physical
Physical
Link
Network
Server Application
Simulation

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

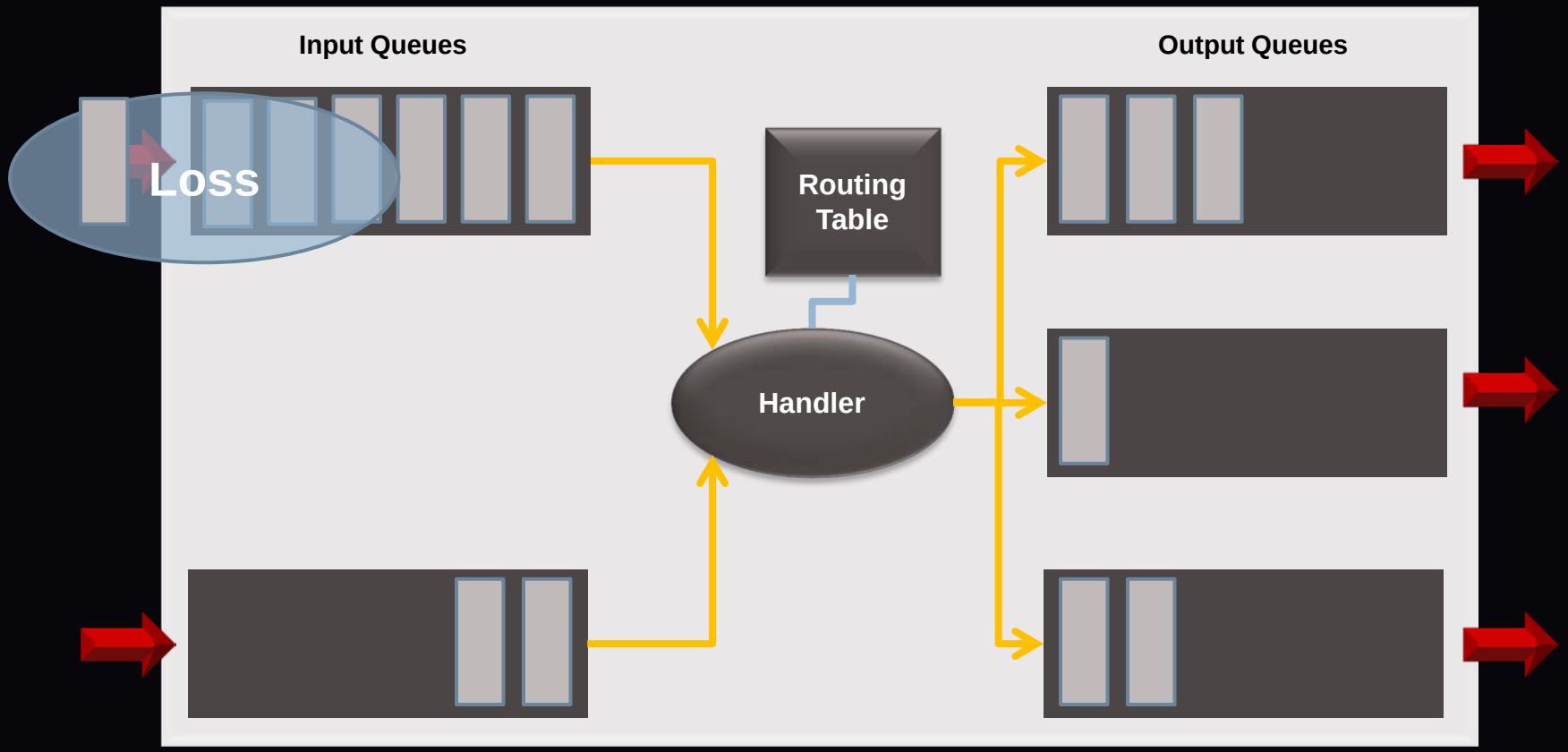
Bandwidth

- 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

- Loss is good
- Loss is the Internet's way of protecting itself from overload
- Principally caused by congestion: a router can't cope with the throughput OR it can't copy all incoming traffic on to the desired outgoing route
- End to end protocols need to detect loss
  - TCP does this for you
- Protocols need to rate limit because not doing so will likely make the situation worse

Loss : Network Perspective



Bandwidth and Latency: Wired

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- 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

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- 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 Q1, 2011
-	Global	2.1
1	South Korea	14.4
2	Hong Kong	9.2
3	Japan	8.1
4	Netherlands	7.5
5	Romania	6.6
6	Czech Rep.	6.5
7	Latvia	6.3
8	Switzerland	6.2
9	Belgium	6.1
10	Ireland	5.6
…		
14	United States	5.3

Average connection speed by country, Q1 2011. Based on Akamai, State of the Internet, 4(2)

Effect of distance on throughput

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Distance from Server to User (miles)	Network Latency (ms)	Typical Packet Loss (%)	Throughput (Mbps) :Quality	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)

Why NVEs are unique

- NVEs are not “standard” network applications
- Unlike video/audio streaming, or web browsing, in an NVE or NG client, networking is NOT the main activity: rendering probably is
- Some information changes very quickly and smoothly
  - E.G. player positions
- Can incorporate other web-enabled media
  - Audio/video
- Often require bulk download of assets
- NVEs mix different types of requirement

Why NVEs are unique

- Internet is built to move bulk traffic, but not for end to end speed
- You can’t reserve bandwidth (except in certain situations)
- Latency and bandwidth will vary
- Streaming for audio and video will buffer significantly and loss is not important
- For NVEs loss can be critical, but also buffering is usually not appropriate

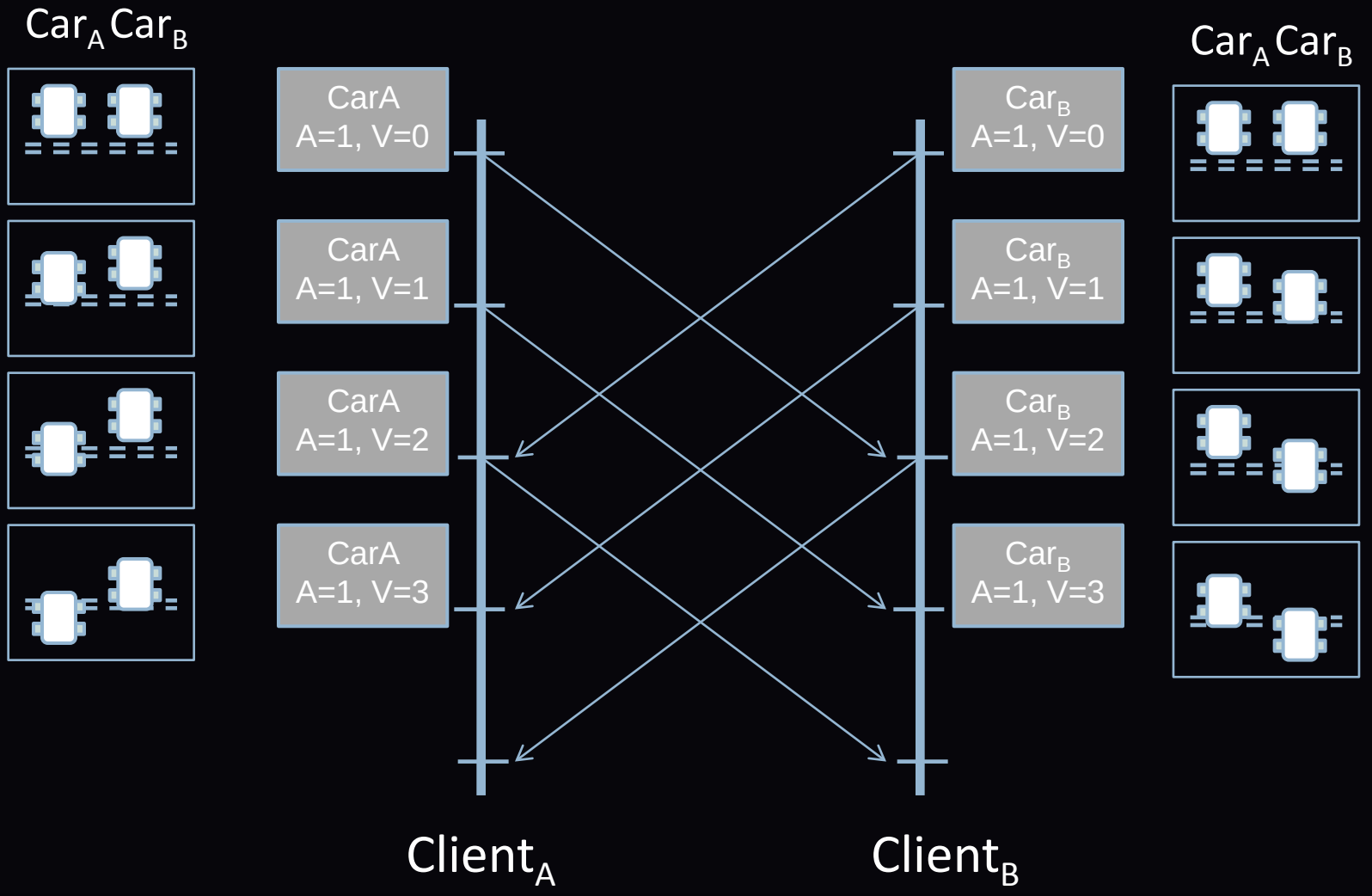
Consistency : System Perspective

- 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

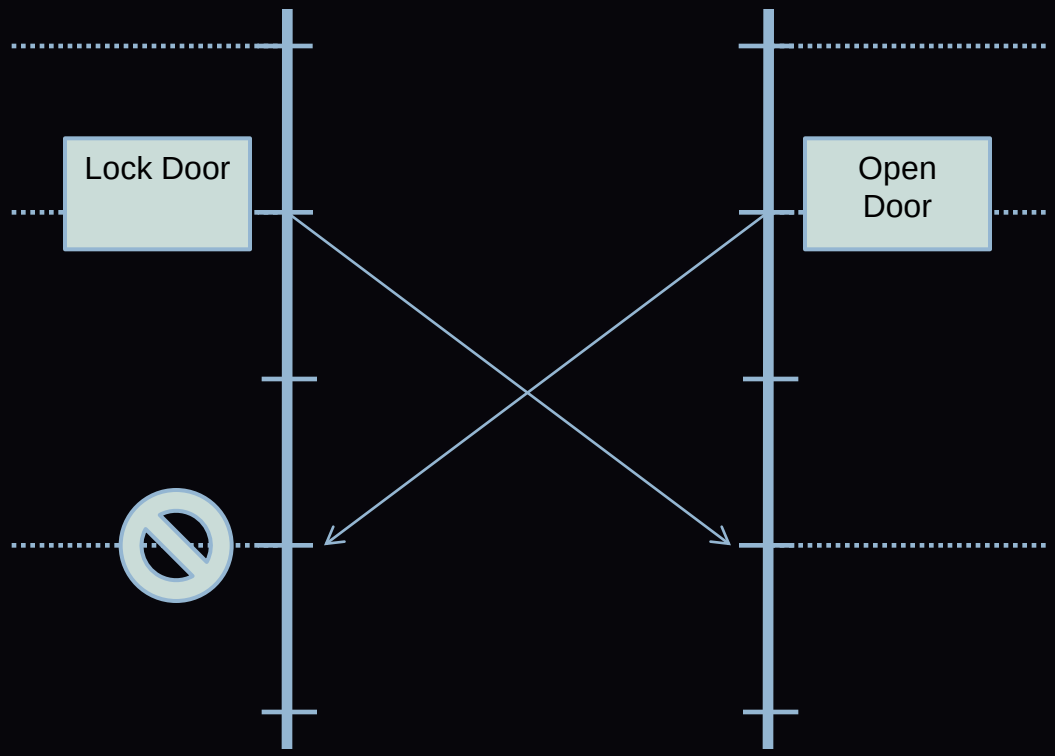
Consistency : User Perspective

- 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

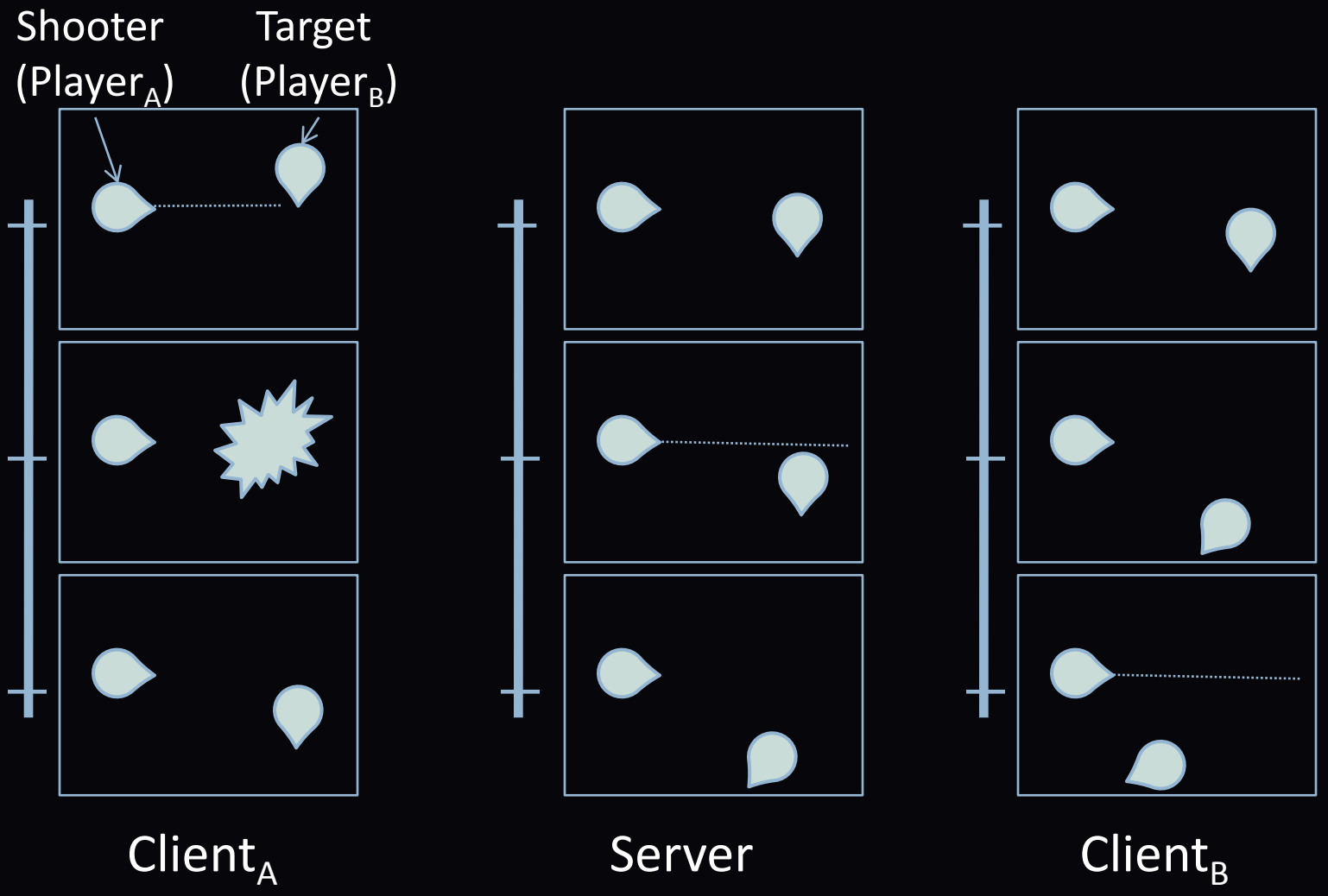
Impact: Timing Activity Onset



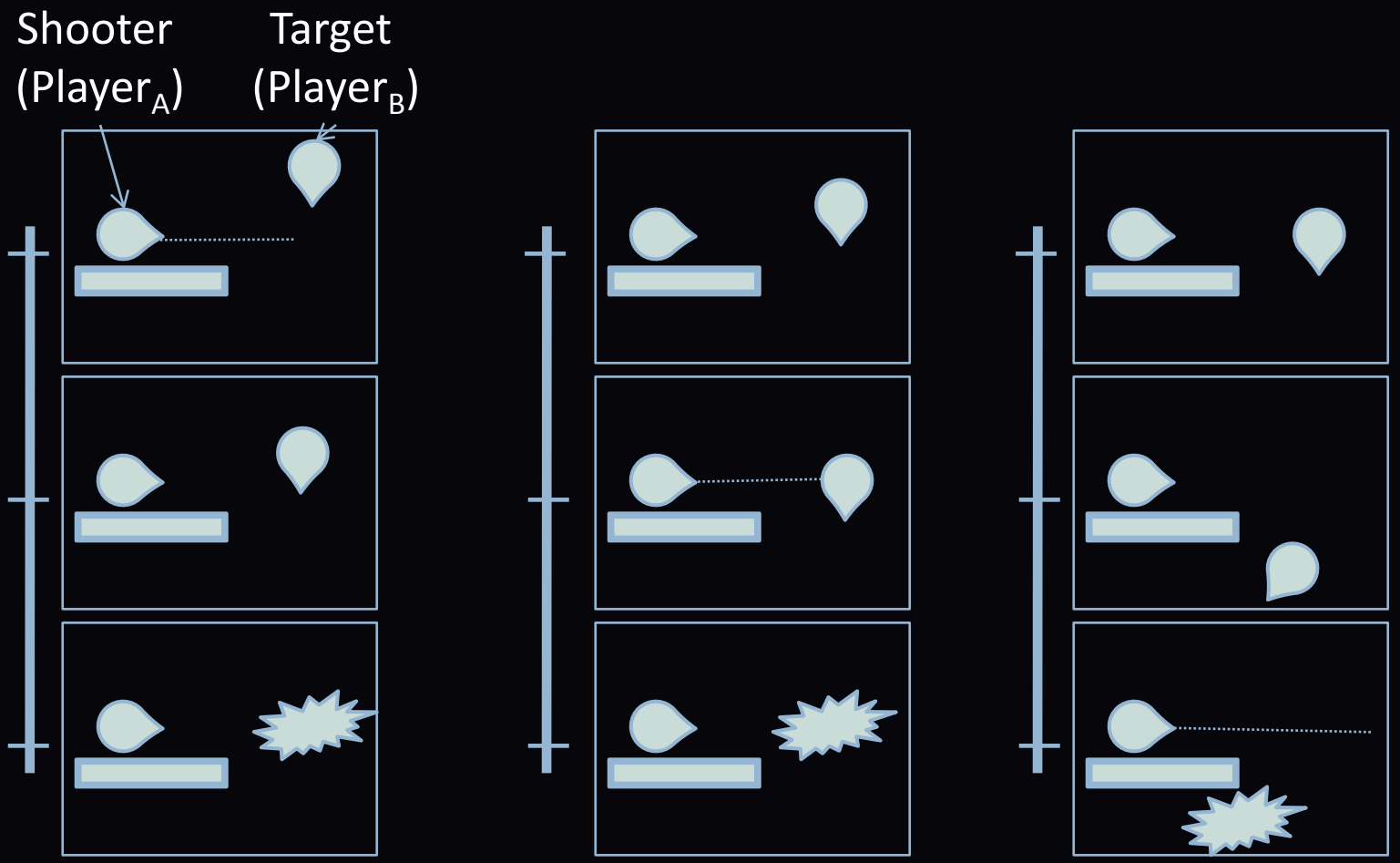
Impact: Inconsistent State Changes



Impact: Fireproof Players



Impact: Shooting Around Corners



Latency Acceptability

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

Bandwidth Requirements

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- 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)

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 network probably runs a NAT
  - You have one address from your ISP
  - You might pay to have this be a static IP address
- NATs complicate

Comments on NATs

- Many types of NAT, port static, symmetric, etc.
- You can bypass NATs with “hole-punching” techniques
- Many game middleware have a function for this BUT
  - Game providers need to provide a rendezvous service
  - Need a packet relay service when it fails
- For a peer to peer game, middleware tries to assess which client has best connectivity
- NATs often are combined with the functionality of firewalls whose role is to protect the LAN from malicious incoming traffic

Summary

- Broadband accessibility is growing
- NVEs and NGs tend to demand a lot from the network
  - Some games have low latency requirements
  - Packet rates vary enormously depending on the game type
- The immediate impact of Internet performance can lead to de-synchronization and player frustration
- The Internet is not symmetrically connected