

SyncCast: Synchronized Dissemination in Multi-site Interactive 3D Tele-immersion

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<http://cairo.cs.uiuc.edu/>

<http://cairo.cs.uiuc.edu/teleimmersion/>

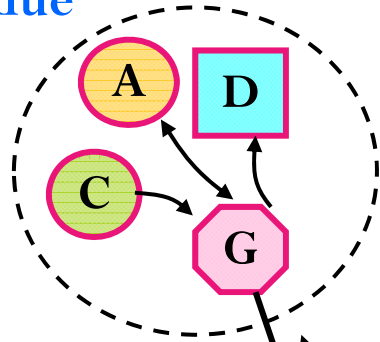
Tele-immersive Environment



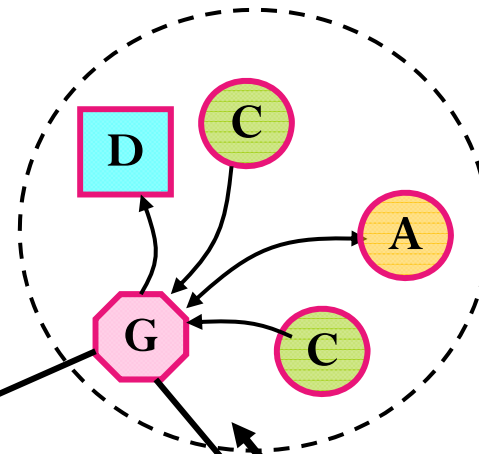
Photo courtesy of Prof. Ruzena Bajcsy.

Multi-site 3DTI Communication

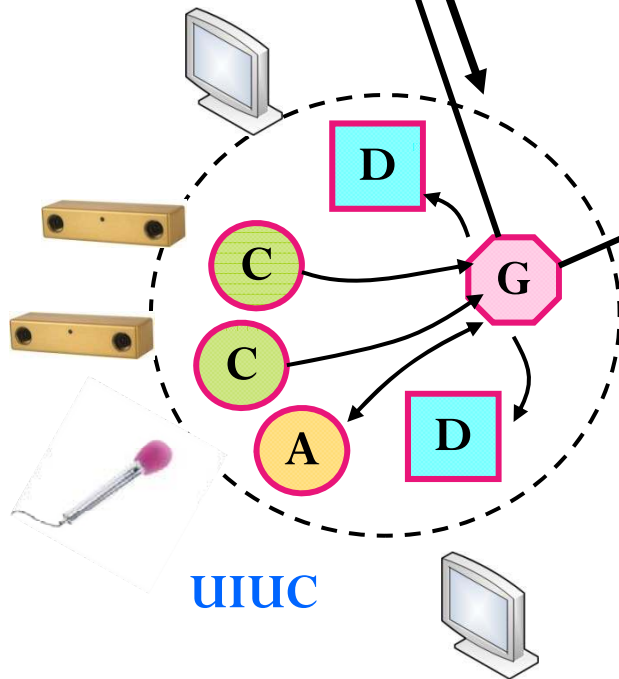
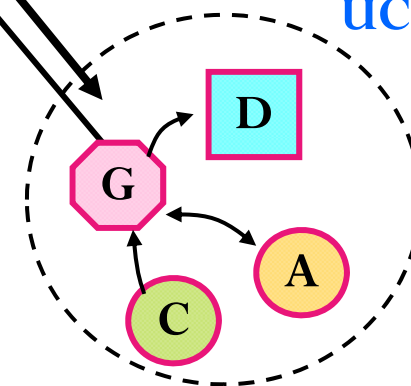
Purdue



UC Berkeley



UC Davis



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service gateway



display



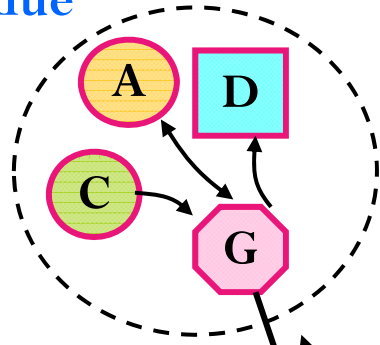
camera



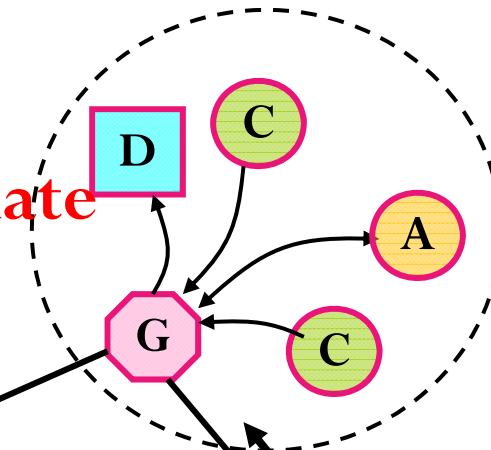
audio in/out

Multi-site 3DTI Communication

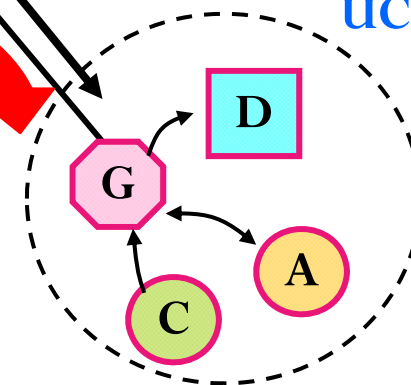
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intermediate
site

sender

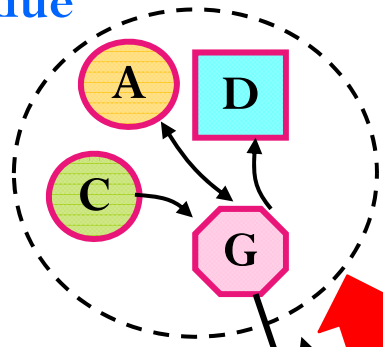
receiver

UIUC

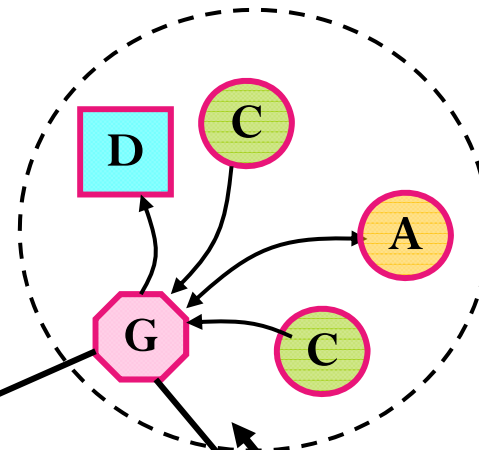


P1: Delay and Bandwidth Constraint

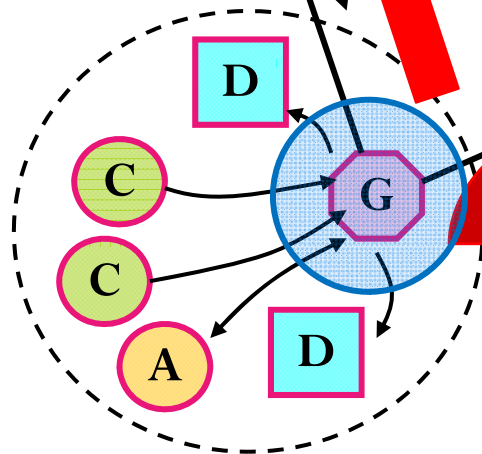
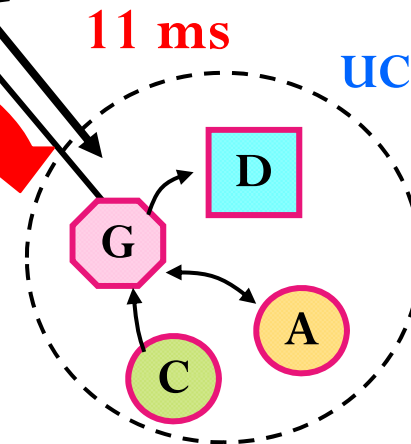
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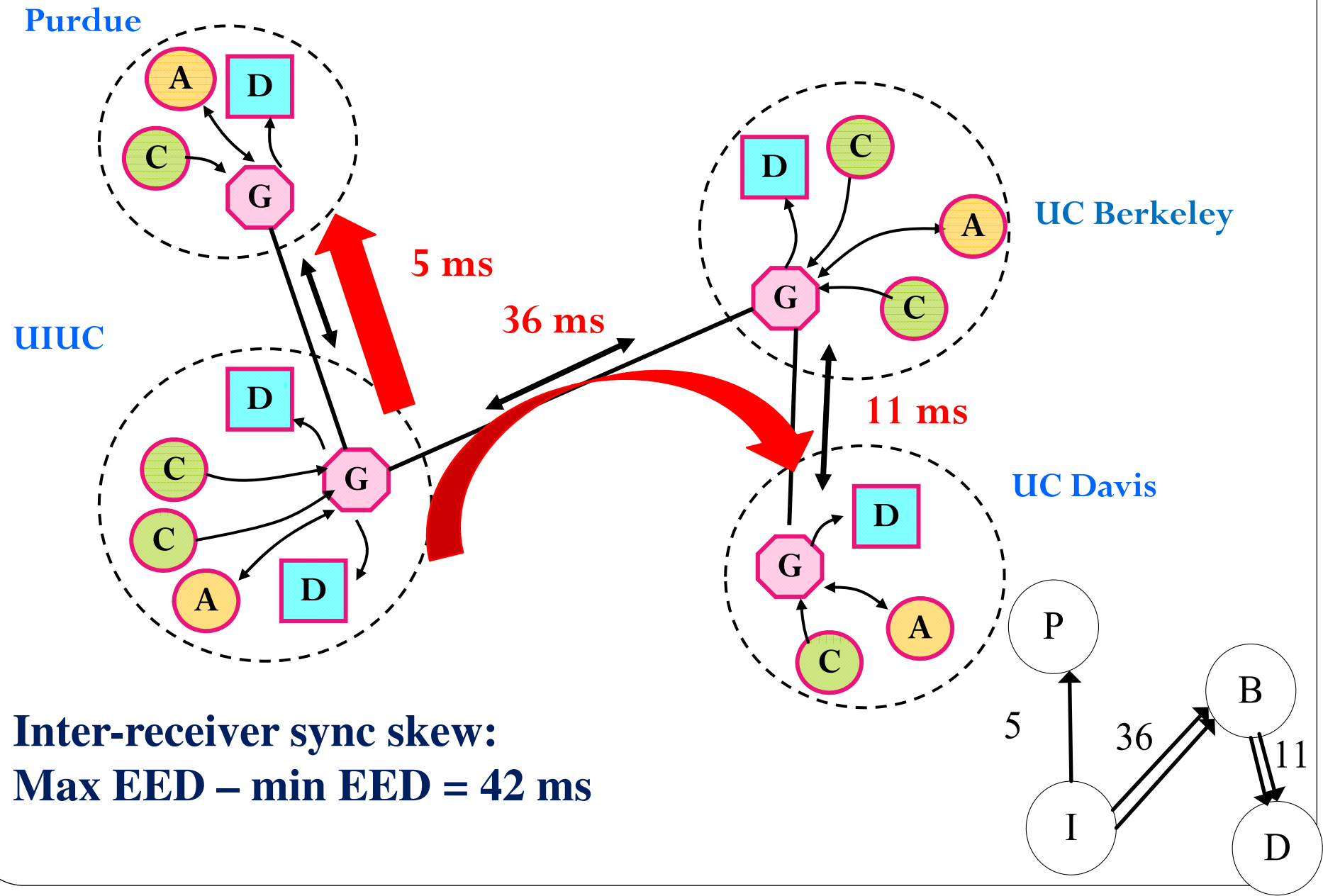
5 ms

36 ms

11 ms

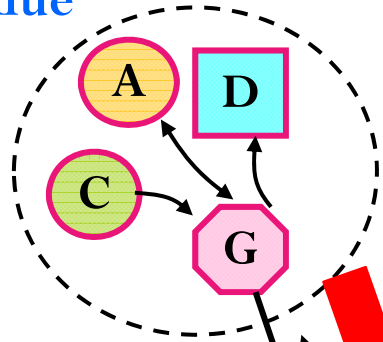
1. Delay constraint: interactivity
2. Bandwidth constraint

P2: Inter-receiver Sync Skew

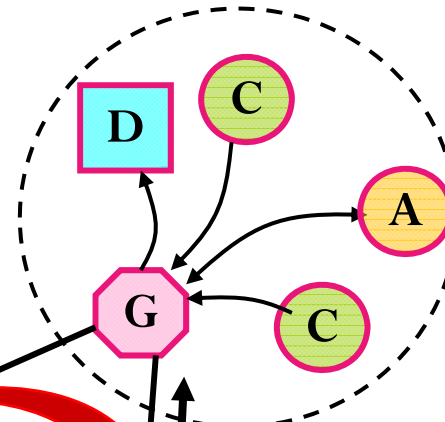


P3: Inter-sender Sync Skew

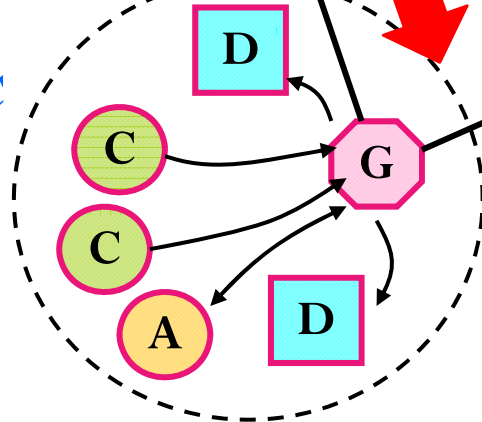
Purdue



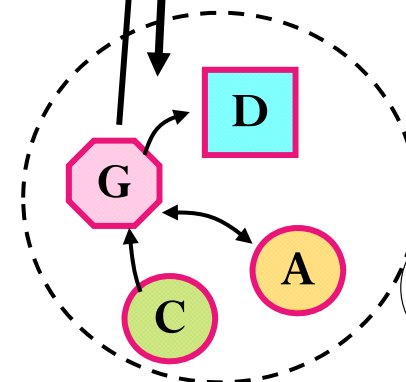
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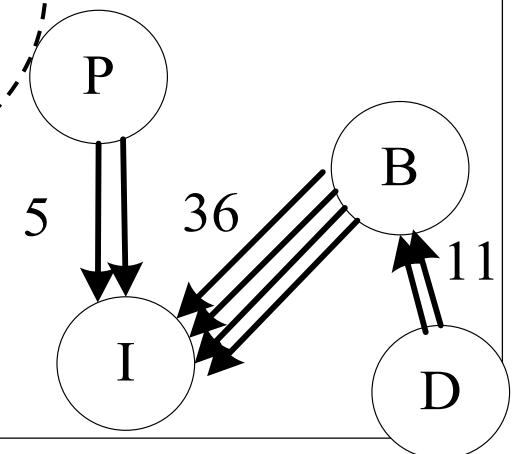


5 ms

36 ms

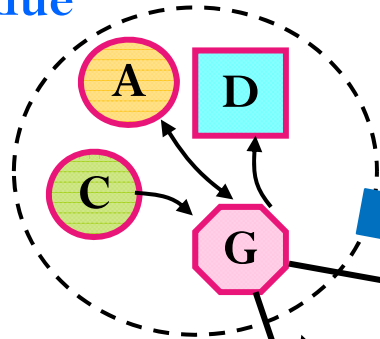
11 ms

Inter-sender sync skew:
Max EED – min EED = 42 ms

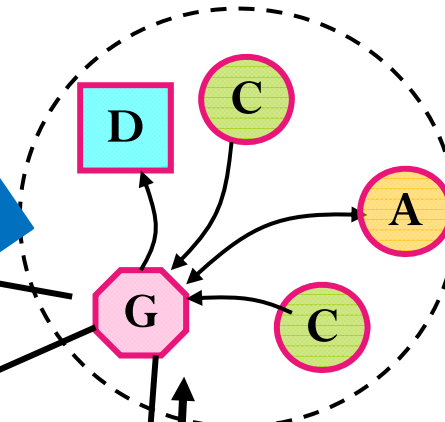


P4: Inter-stream Sync Skew

Purdue



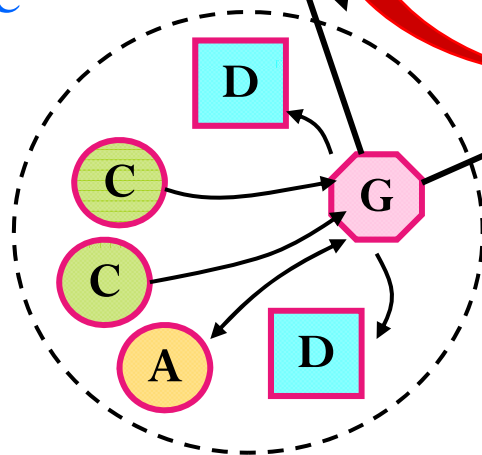
37 ms



UC Berkeley

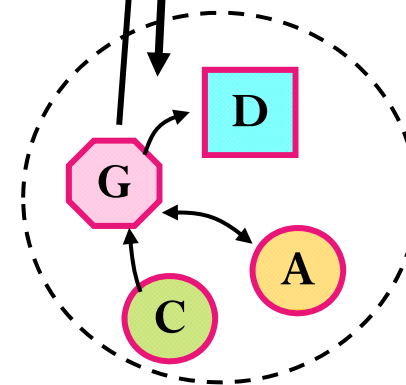
5 ms

UIUC



11 ms

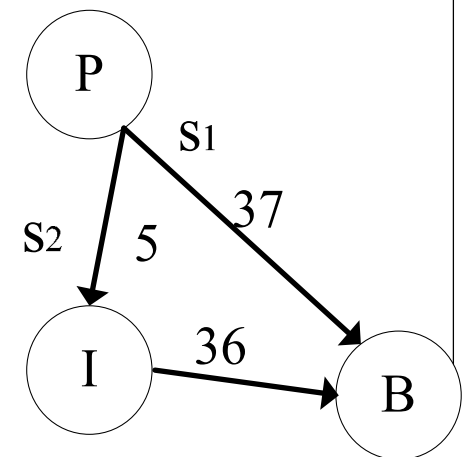
UC Davis



36 ms

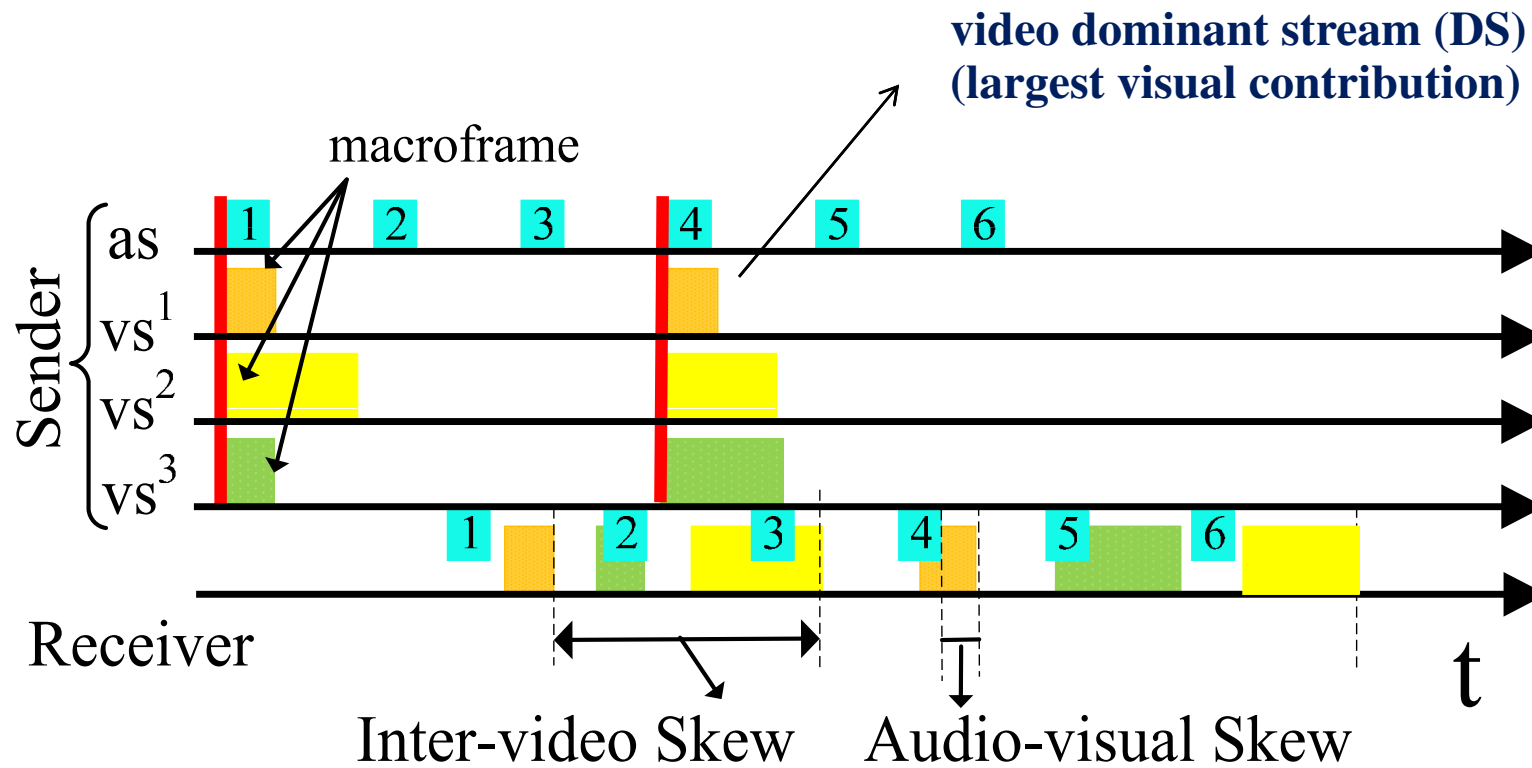
Inter-stream sync skew:
Max EED – min EED = 4 ms

Inter-video skew
Audio-visual skew



Inter-stream Sync Skew

- **Video multi-stream synchronization**
- **Audio-visual synchronization**



Problem Statement

- **Previous work did not study all synchronization constraints!**
- **We want to design a multi-site 3DTI dissemination scheme that minimizes EED with synchronization and bandwidth constraints.**

Interactivity

- EED decides the interactivity
- Minimize EED for dissemination paths

Synchronization Constraint

- Inter-stream sync: inter-video and audio-visual
- Inter-site sync: inter-sender and inter-receiver

Bandwidth Constraint

- Inbound bandwidth
- Outbound bandwidth

What we consider ...

Stream prioritization
Different visual contribution

Path prioritization
Latency vs. fairness

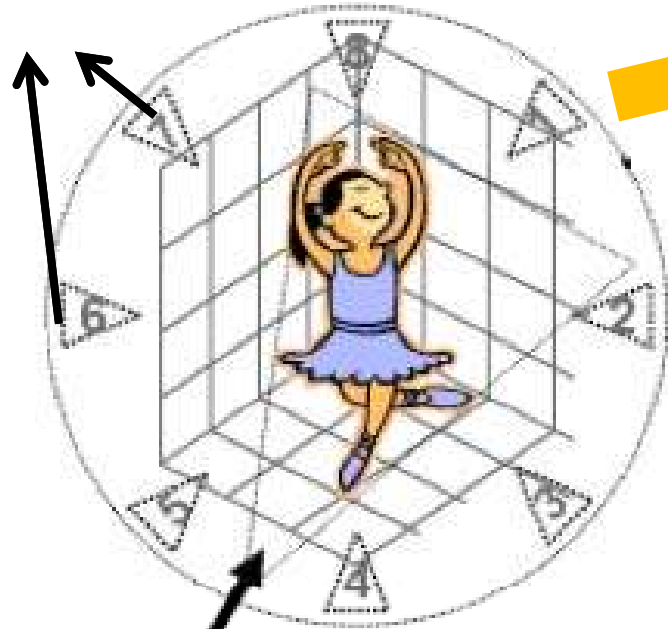
Other heuristics at sender site
Bandwidth preservation policy

Stream Prioritization

Contribution Factor (CF):

$$CF(vs) = \vec{O}_{vs} \cdot \vec{O}_u$$

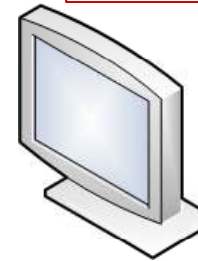
\vec{O}_{vs} video stream



user view

\vec{O}_u

3D Free Viewpoint
Renderer



Dominant Stream (DS): the video stream with the largest CF to user view

Non-dominant stream (NDS):

$CF > 0$

There is a video DS for each sender-receiver pair.

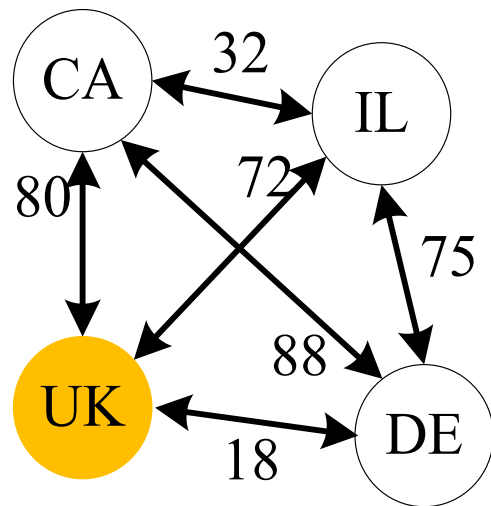
Yang et al, A multi-stream adaptation framework for bandwidth management in 3D tele-immersion, ACM NOSSDAV 2006

Stream Prioritization

- Priority is given to streams with greater visual contributions.
- We divide all streams into two service classes (SC).



- Dissemination of all audio and video DS

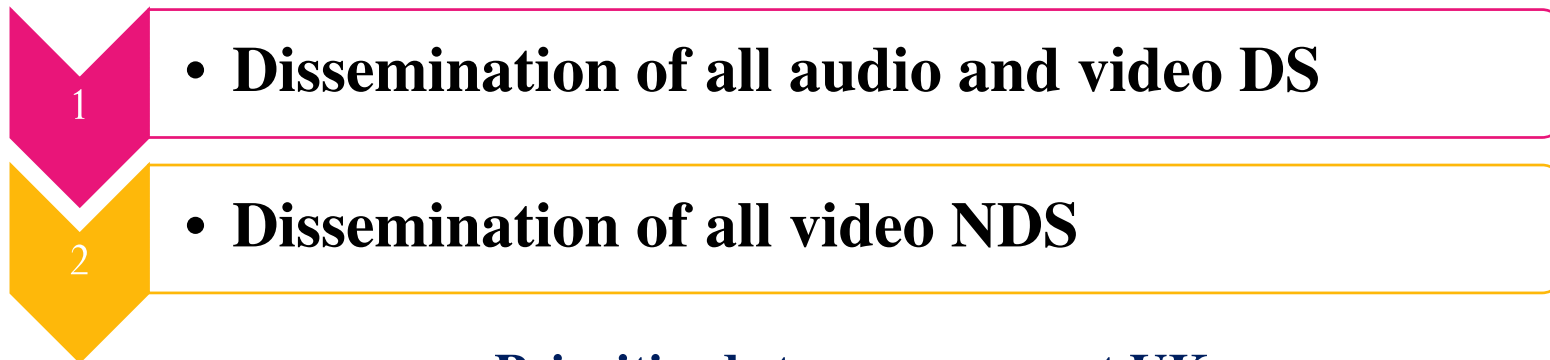


Prioritized stream queue at UK:
SC1 = {S1(IL), S1(CA), S2(DE)}

SND	RCV	DS (CF)	
UK	CA	S1 (.8)	
UK	IL	S1 (.9)	
UK	DE	S2 (.8)	

Stream Prioritization

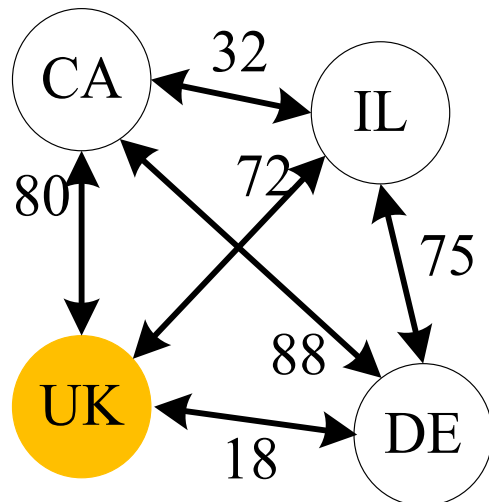
- Priority is given to streams with greater visual contributions.
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Prioritized stream queue at UK:

SC1 = {S1(IL), S1(CA), S2(DE)}

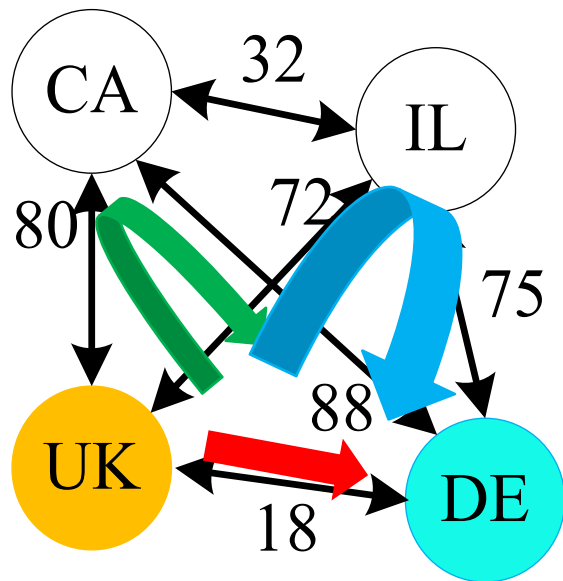
SC2 = {S2(CA), S2(IL), S1(DE), S3(DE), S3(CA)}



SND	RCV	DS (CF)	NDS (CF)
UK	CA	S1 (.8)	S2 (.4), S3 (.1)
UK	IL	S1 (.9)	S2 (.4)
UK	DE	S2 (.8)	S1 (.3), S3 (.3)

Path Prioritization

- A stream from a sender site to a receiver can follow multiple paths
- **Latency: EED between the sender and receiver**



3 paths for S3 from UK to DE:

(1) UK -> DE 18 ms

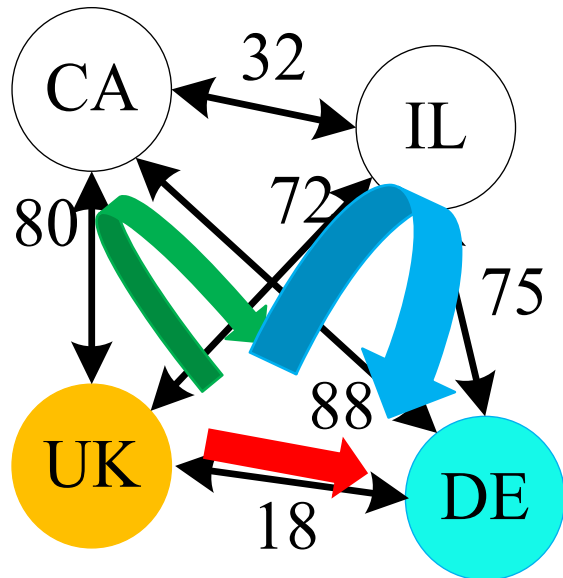
(2) UK -> IL -> DE 147 ms

(3) UK -> CA -> DE 168 ms

SND	RCV	DS	NDS
UK	CA	S1	S2, S3
UK	IL	S1	S2
UK	DE	S2	S1, S3

Path Prioritization

- A stream from a sender site to a receiver can follow multiple paths
- Latency: EED between the sender and receiver
- **Unfairness (Q): number of sites on the path which does not request a stream as DS or NDS**



3 paths for S3 from UK to DE:

(1) UK -> DE 18 ms (Q = 0)

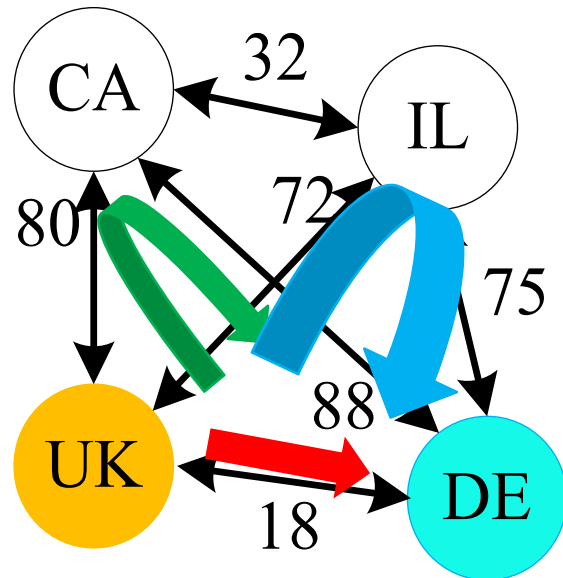
(2) UK -> IL -> DE 147 ms (Q = 1)

(3) UK -> CA -> DE 168 ms (Q = 0)

SND	RCV	DS	NDS
UK	CA	S1	S2, S3
UK	IL	S1	S2
UK	DE	S2	S1, S3

Path Prioritization

- A stream from a sender site to a receiver can follow multiple paths
- Latency: EED between the sender and receiver
- Unfairness (Q): number of sites on the path which does not request a stream as DS or NDS
- **Our policy: fairness first, latency next (to preserve bandwidth)**



3 paths for S3 from UK to DE:

(1) UK -> DE 18 ms (Q = 0)

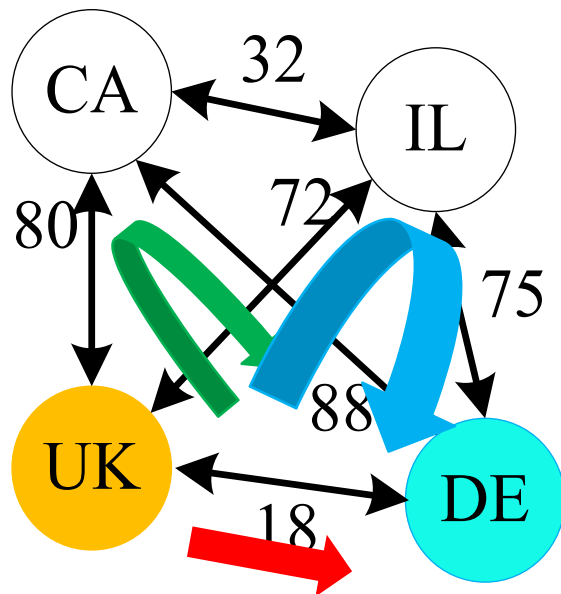
(2) UK -> CA -> DE 168 ms (Q = 0)

(3) UK -> IL -> DE 147 ms (Q = 1)

SND	RCV	DS	NDS
UK	CA	S1	S2, S3
UK	IL	S1	S2
UK	DE	S2	S1, S3

Path Prioritization

- A stream from a sender site to a receiver can follow multiple paths
- Latency: EED between the sender and receiver
- Unfairness (Q): number of sites on the path which does not request a stream as DS or NDS
- Our policy: fairness first, latency next (to preserve bandwidth)
- Other heuristics: a sender site ONLY relays other senders' DS



3 paths for S3 from UK to DE:

(1) UK -> DE 18 ms (Q = 0)

~~(2) UK -> CA -> DE 168 ms (Q = 0)~~

(3) UK -> IL -> DE 147 ms (Q = 1)

If CA is also a sender site ...

Path EED and Synchronization Skews

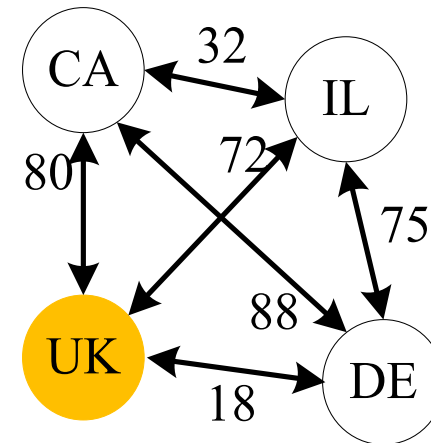
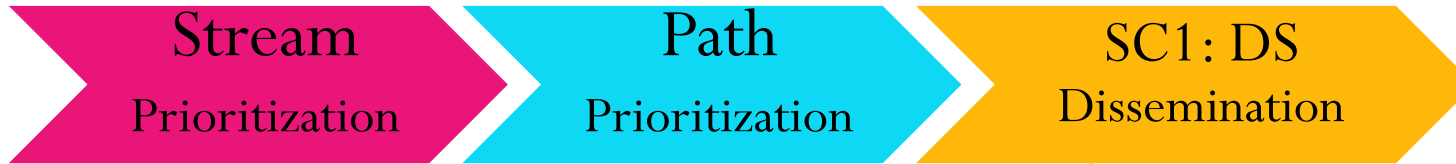
- **EED of DS paths decide the inter-sender/inter-receiver skews**
 - Video DS have the greatest visual contributions
 - Video DS are given the top priority in dissemination
 - Video NDS may not arrive at the receivers
- **Inter-stream skews are decided by EED of both DS and NDS paths**
 - ZERO audio-visual skew (audio and video DS same path)
 - Inter-video synchronized at the receiver jitter buffer of a fixed size throughout the system

SyncCast Design (Initialization)



- 1. Stream Prioritization**
- 2. Path Prioritization**
- 3. Constraint Setup**
 - **Max BW_{in} = 3 streams**
 - **Max BW_{out} = 3 streams**
 - **Max inter-stream skew = 50 ms**
 - **Max inter-site skew = 50 ms**

SyncCast Design (DS Dissemination)

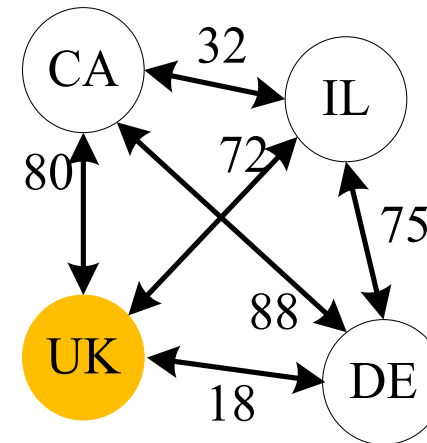
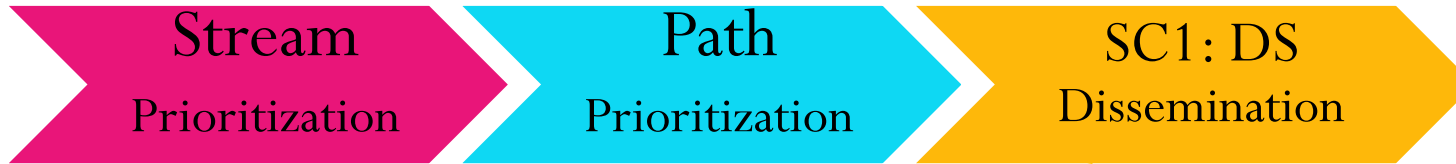


Prioritized stream queue at UK:
SC1 = {S1(IL), S1(CA), S2(DE)}

- S1: UK -> IL (80)**
- S1: UK -> CA (72)**
- S2: UK -> DE (18)**

SND	RCV	DS (CF)
UK	CA	S1 (.8)
UK	IL	S1 (.9)
UK	DE	S2 (.8)

SyncCast Design (DS Dissemination)



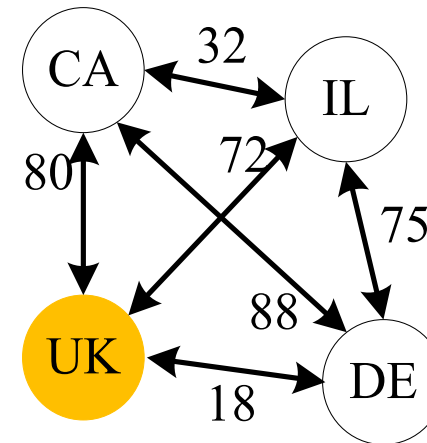
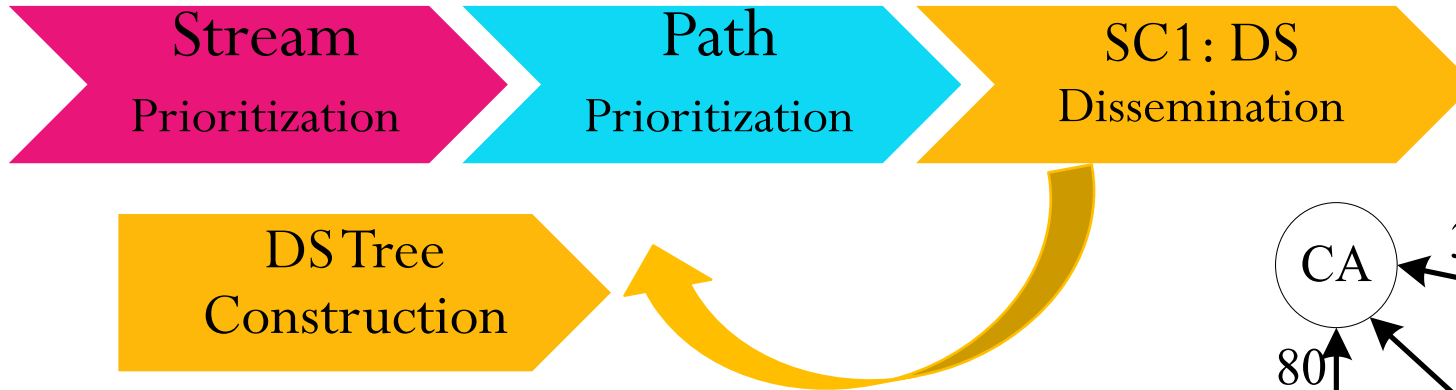
Prioritized stream queue at UK:
SC1 = {S1(IL), S1(CA), S2(DE)}

- S1: UK -> IL (80)**
- S1: UK -> CA (72)**
- S2: UK -> DE (18)**

Inter-receiver sync skew!

SND	RCV	DS (CF)
UK	CA	S1 (.8)
UK	IL	S1 (.9)
UK	DE	S2 (.8)

SyncCast Design (DS Dissemination)



Prioritized stream queue at UK:
SC1 = {S1(IL), S1(CA), S2(DE)}

S1: UK -> IL (80)

S1: UK -> CA (72)

~~S2: UK -> DE (18)~~

~~S2: UK -> IL -> DE (147)~~

~~S2: UK -> CA -> DE (168)~~

S2: UK -> DE (18)

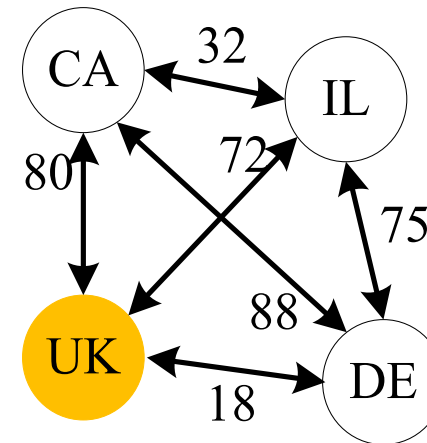
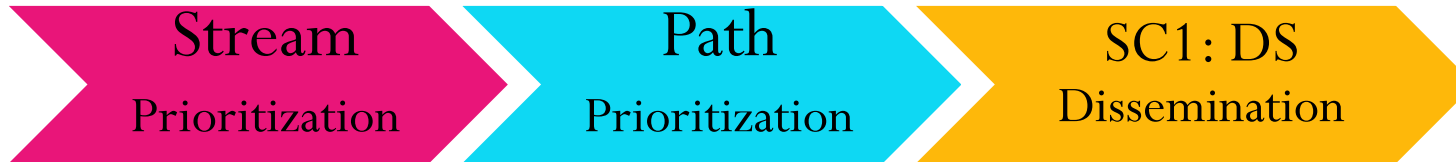
Inter-receiver sync

Inter-receiver sync

Inter-receiver sync
and CA is a sender

SND	RCV	DS (CF)
UK	CA	S1 (.8)
UK	IL	S1 (.9)
UK	DE	S2 (.8)

SyncCast Design (DS Dissemination)



Prioritized stream queue at UK:
SC1 = {S1(IL), S1(CA), S2(DE)}

- S1: UK -> IL (80)**
- S1: UK -> CA (72)**
- S2: UK -> DE (18)**

Find alternative path for UK->IL: NOT POSSIBLE!

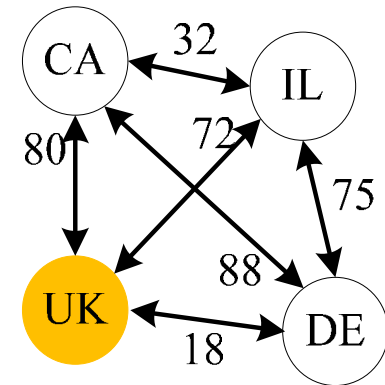
Violate Sync Constraint:
Introduce latency at the receiver for S2: UK->DE

SND	RCV	DS (CF)
UK	CA	S1 (.8)
UK	IL	S1 (.9)
UK	DE	S2 (.8)

SyncCast Design (NDS Dissemination)



- **Select a parent node which is either a sender site or a site has received the stream with synchronization and bandwidth constraints**
- **Try to reduce the case when the sender directly sends a NDS to a receiver in order to save the sender bandwidth**



Prioritized stream queue at UK:

SC2 = {S2(CA), S2(IL), S1(DE), S3(DE), S3(CA)}

S2: UK->DE->CA (106)

S2: UK->DE->IL (92)

S1: No Path (UK, DE) ← inter-stream skew & BW

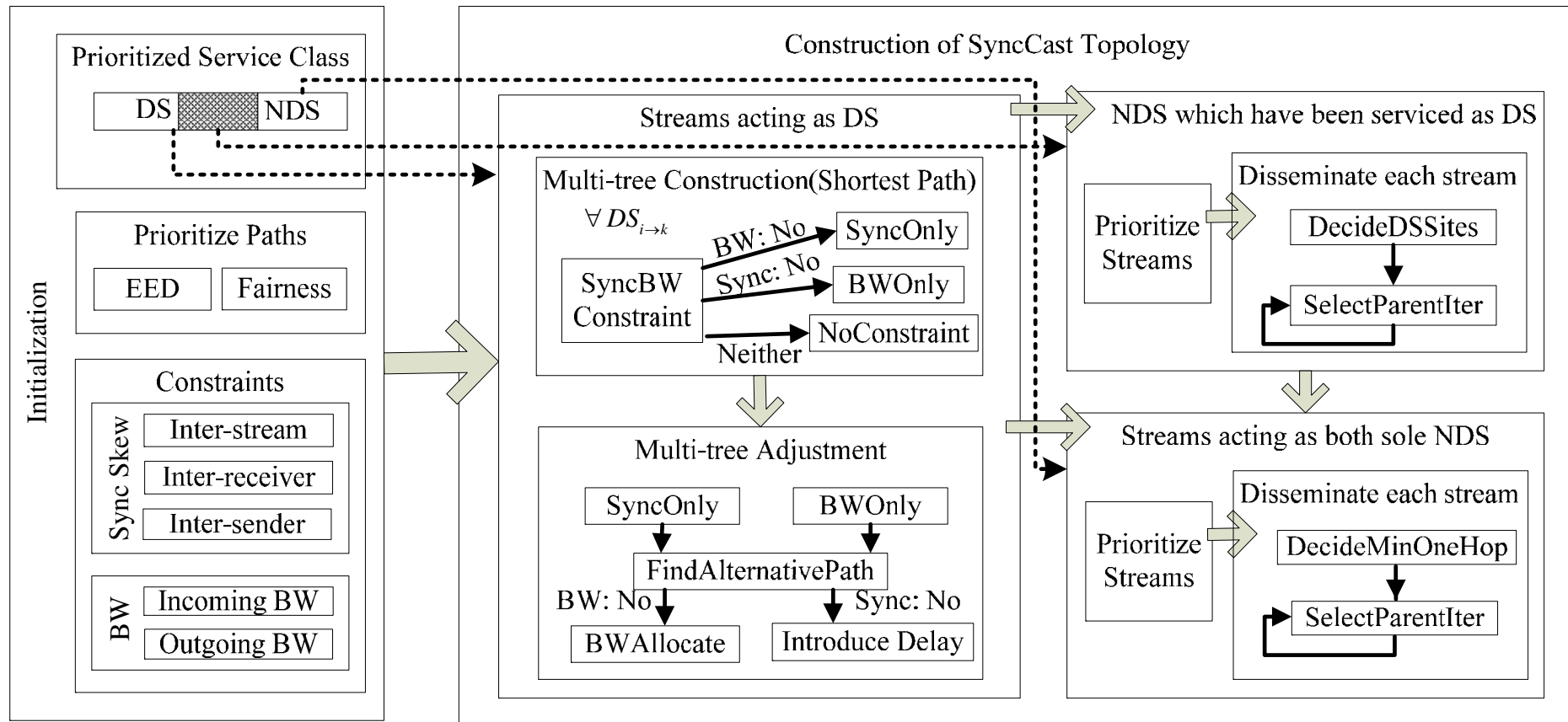
S3: No Path (UK, DE) ← BW constraints

S3: No Path (UK, CA) ← BW constraints

SND	RCV	DS	NDS
UK	CA	S1	S2, S3
UK	IL	S1	S2
UK	DE	S2	S1, S3

SyncCast Design

MORE DETAILS? PLS REFER TO THE PAPER !



Experiment Setup

- **Internet delays are collected from PlanetLab nodes**
 - **Covering 3 continents: Asia, Americas, Europe**
 - **Firewall issues and poor links are considered**
- **5-node (2 senders) and 9-node (4 senders) configurations**
 - **Half of nodes are senders**
- **Each sender outputs 8 streams (1 DS and 2 NDS)**
- **User view diversity**
 - **50% of the receiver sites share the same video DS**
 - **Another 50% of the receiver sites share different DS**

We compare SyncCast with ViewCast

	SyncCast	ViewCast
Delay	Minimize delay	Delay bound
Bandwidth	BW bound	BW bound
Path Fairness	Yes	No
Inter-stream skew	Yes	No
Inter-sender skew	Yes	No
Inter-receiver skew	Yes	No

**Z. YANG, W. WU, K. NAHRSTEDT, G. KURILLO, R. BAJCSY,
Enabling Multi-party 3D Tele-immersive Environments with ViewCast,
ACMTOMCCAP, 2009.**

Different network environment (ms)

Network Case: 5C

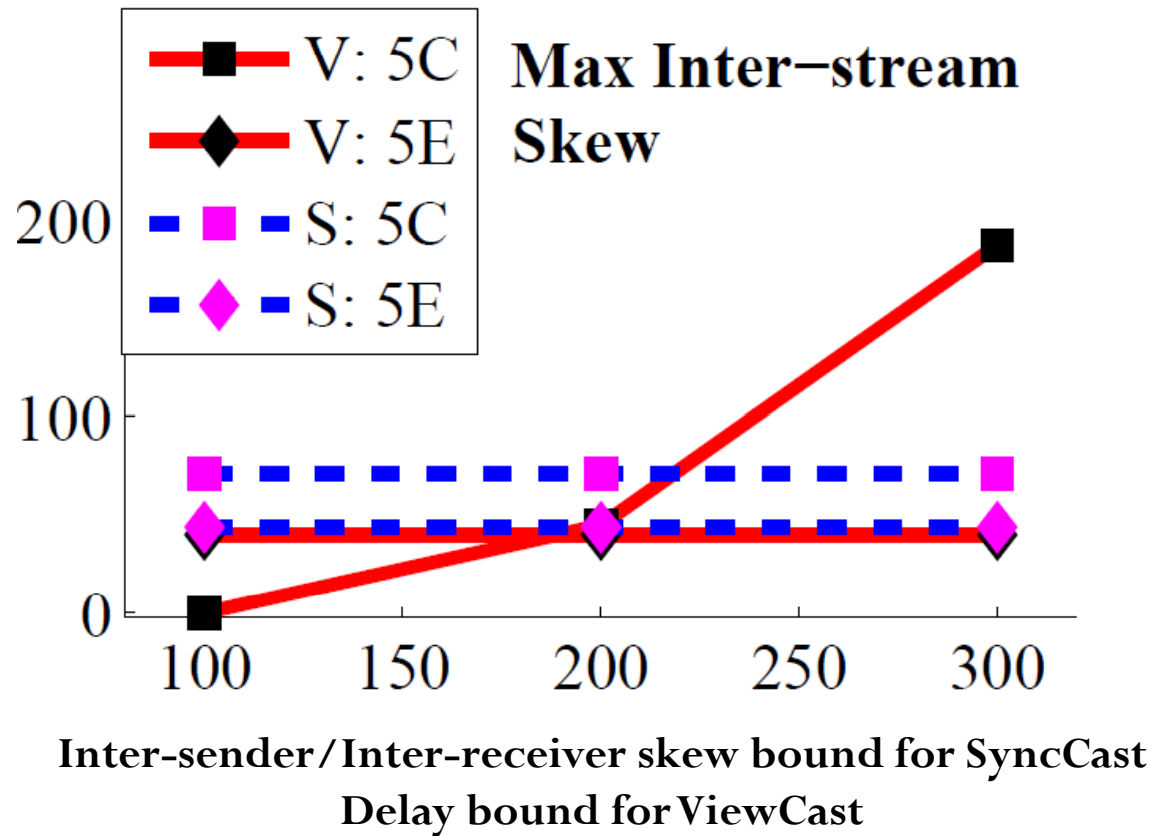
	CA	IL	DE	JP	CN
CA	0	32	88	70	152
IL	32	0	75	109	178
DE	88	75	0	140	123
JP	70	109	140	0	34
CN	152	178	123	34	0

Network Case: 5E

	CA	IL	UK	DE	NY
CA	0	32		88	
IL	32	0	72	75	21
UK		72	0	18	53
DE	88	75	18	0	52
NY		21	53	52	0

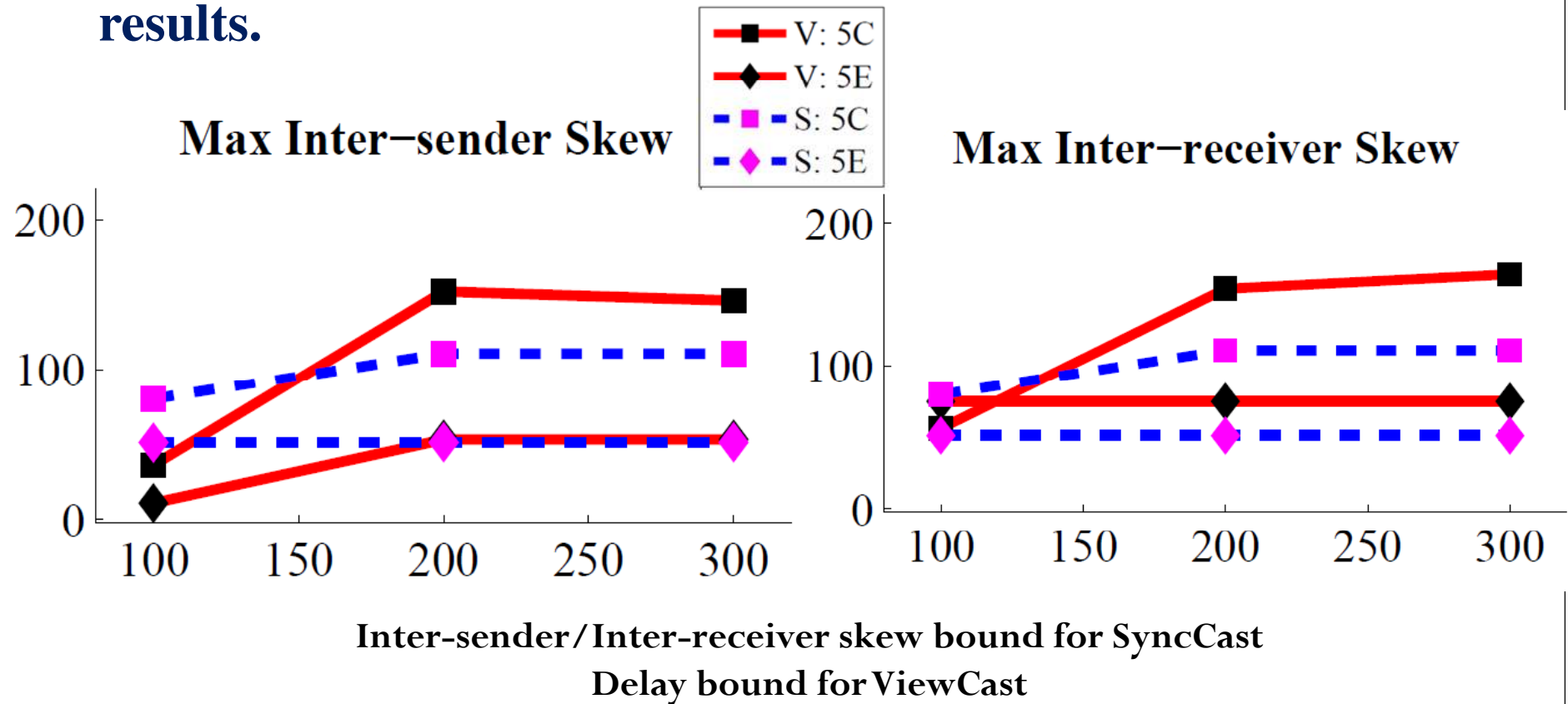
Experiment Results (SyncCast vs ViewCast)

- SyncCast (blue line) consistently bounds the inter-stream skew. ViewCast (red line) has greater variations



Experiment Results (SyncCast vs ViewCast)

- SyncCast (blue line) consistently bounds the inter-sender and inter-receiver skew, and is more reliable than ViewCast results.



Conclusions

- **We propose SyncCast used for multi-site synchronization**
- **Concept of stream service class**
- **Path selection algorithm to improve fairness**
- **Multicast tree (forest) construction**
- **Bound inter-stream and inter-site synchronization**
- **Evaluation using PlanetLab real Internet data**