

# ZScore: A Distributed System for Integrated Mixed Music Composition And Performance

Slavko Zagorac  
Patricia Alessandrini

Goldsmiths College, University of London

# Presentation Outline

**Why** do we need another system?

**What** is it supposed to do ?

**How** can it be achieved ?

Existing technologies

Music Notation

HFT Networking  
high frequency trading

ZScore, current state and demo

# Motivation

Leverage existing state of the art networking solutions to unlock new ways of making music.

What could the next generation of music notation systems look like?

## Blur the Boundaries

electro - acoustic

symbolic - graphic

composer - performer - improviser - audience

# Mission

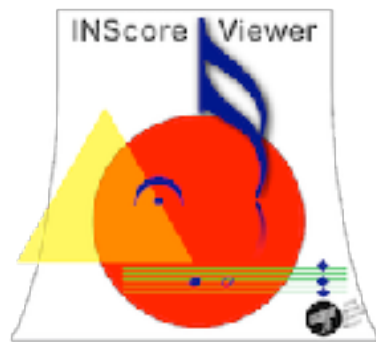
What kind of a system would allow for:

- integrated composition and performance
- real-time notation distribution over a network
- mixed notation scores

(symbolic, graphic, algorithmic, interactive ...)

for a full-size orchestra ?

# Networked Music Notation



INScore  
Native OSC

Quintet.net  
NetCanvas



MAXSCORE

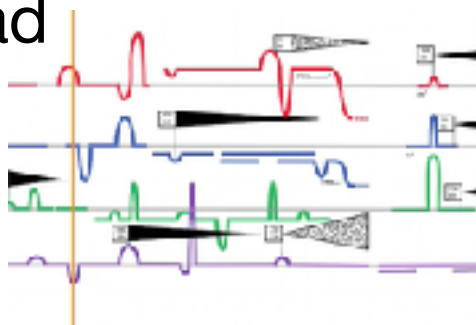


MAX

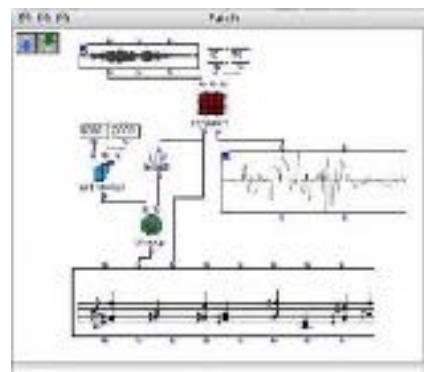


Decibel  
ScorePlayer

iPad



OpenMusic



ODOT

dfscore



Node.js / SVG

# 2 Hats System Requirements



Performance



Simplicity

Scalability  
(1 - 100s of nodes, the same QoS)

User-friendly, Portable, Familiar

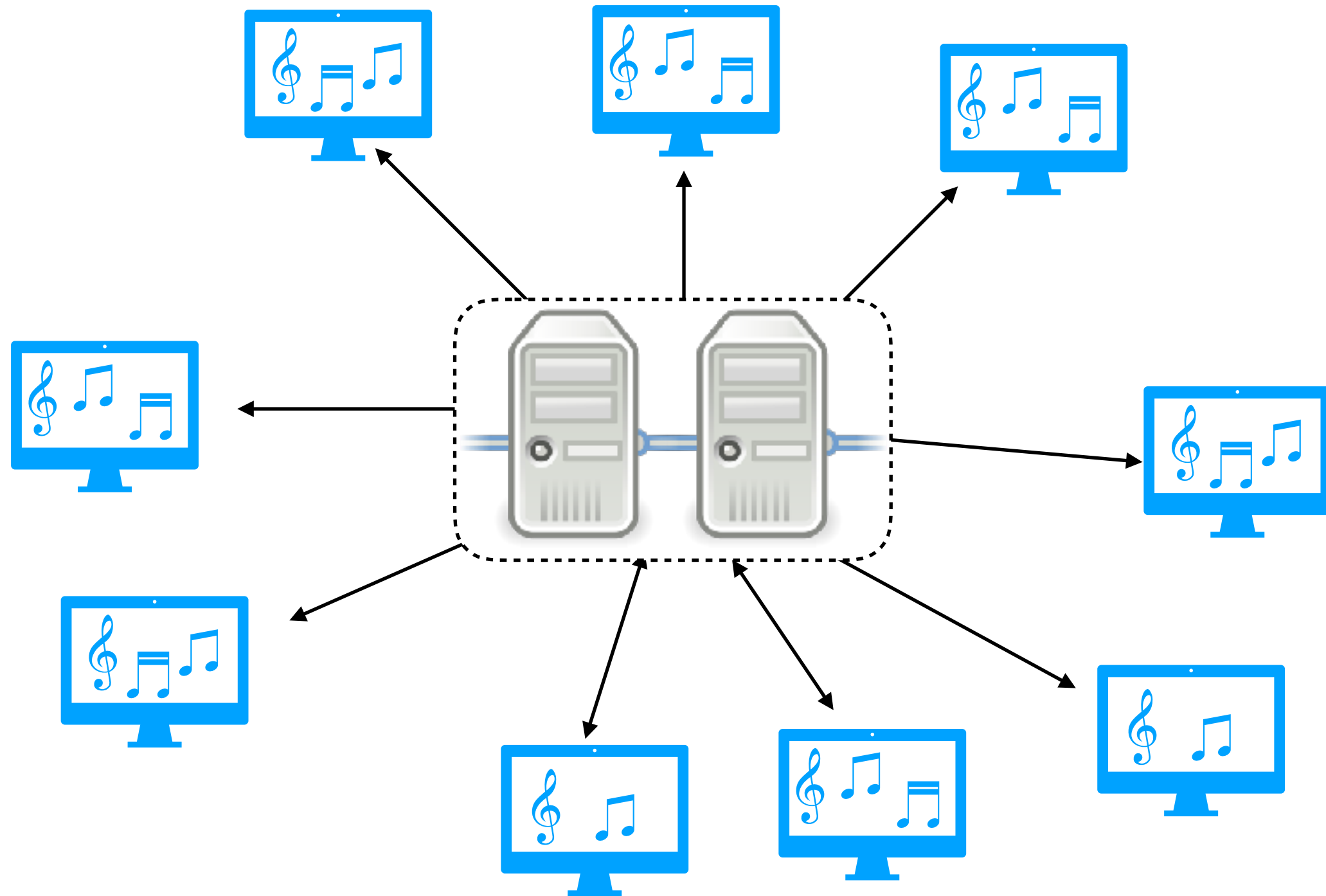
Reliability  
(works all the time, every time)

Unconstrained composition

Accurate  
scheduling / synchronisation

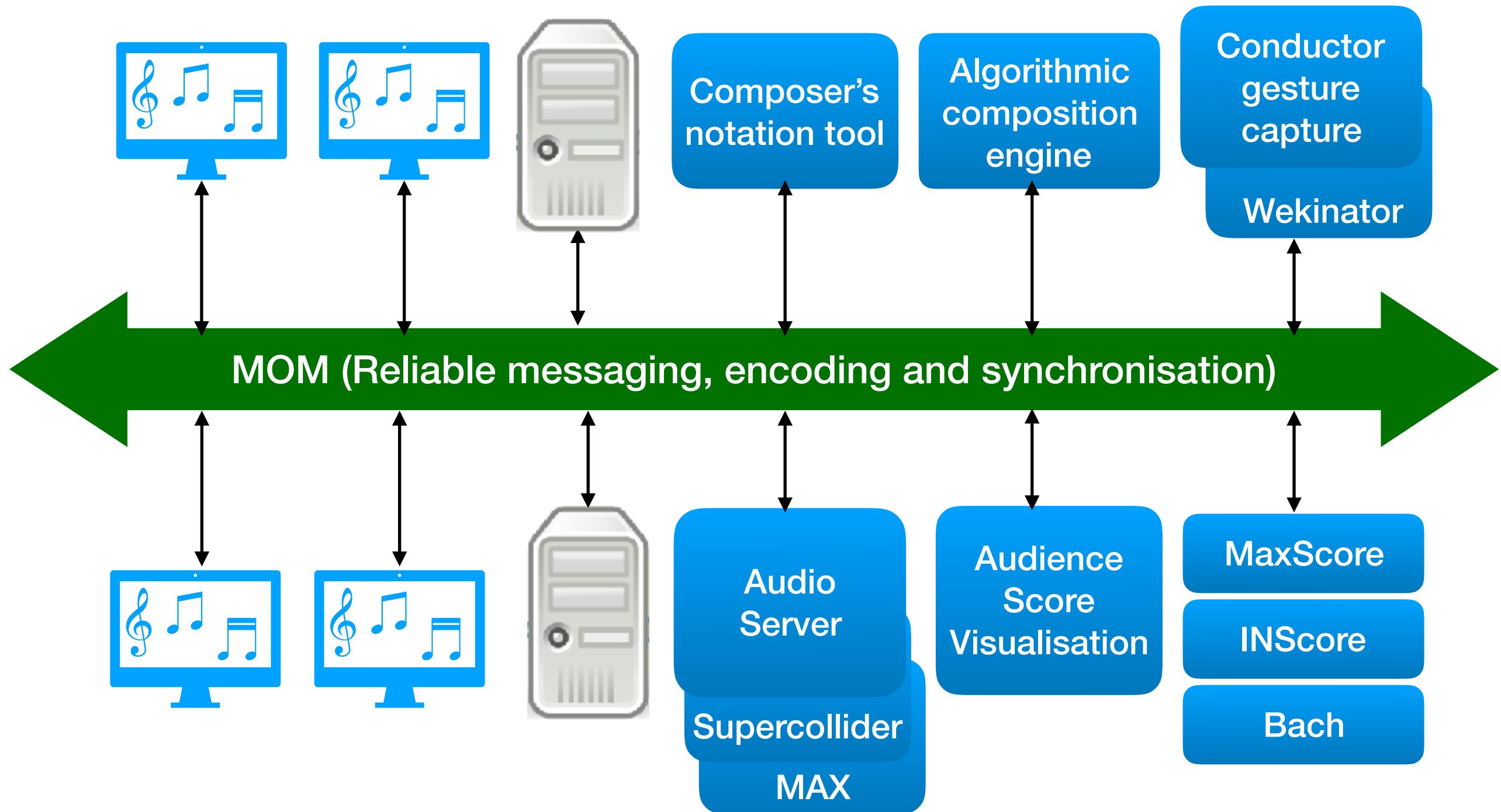
Ample performer preparation time

# Client - Server Architecture



# Distributed Systems

## Message Oriented Middleware (MOM)





# Messaging

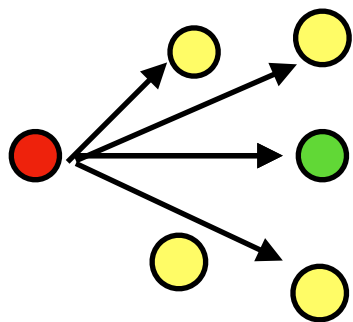
Open Sound Control (OSC)

-> User Datagram Protocol (UDP) -> Unicast

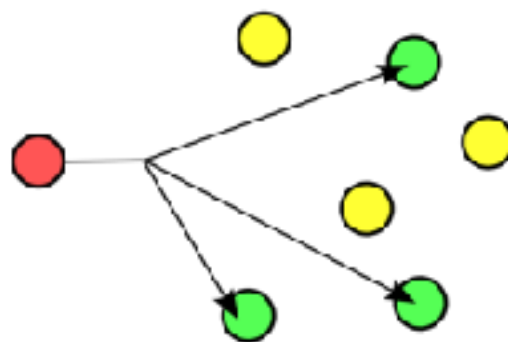
UDP: lightweight, connectionless, **non-guaranteed** delivery

TCP: reliable (ACK), lower throughput

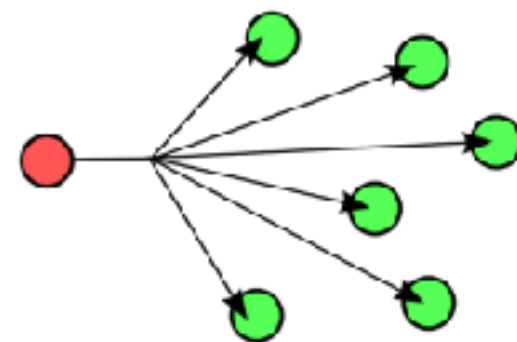
Unicast



Multicast



Broadcast



## Reliable UDP Multicast

(Negative acknowledgment, NACK)

# Score Data Transmission

Bandwidth	Network Type	10 MB transfer time
11 Mbps	Ad-Hoc WiFi (no router)	7.27 sec
100 Mbps	100BASE-TX Ethernet	0.80 sec
600 Mbps	802.11n WiFi	0.13 sec
1 Gbps	1000BASE-T Ethernet	0.08 sec
7 Gbps	802.11ac WiFi (theoretical)	0.01 sec

Max theoretical UDP packet size 64KB

MTU data unit size per transaction (1500B Ethernet)

# Network Synchronisation and Scheduling

OSC - NO mechanism for clock synchronisation

## Network Clock Synchronisation

Network Time Protocol (NTP)  
error <100ms

Precision Time Protocol (PTP)  
sub- $\mu$ s accuracy, not default

GPS time signal 14ns accuracy  
The Global Metronome Project

Application tempo-relative synchronisation

Network jitter compensation

# Open Source HFT Software

1m+ messages per second  
microsecond latencies

## LMAX Disruptor

low-latency, high throughput, non-blocking concurrent data structure

## Aeron

reliable UDP unicast and multicast message transport (OSI L4), SBE encoding

## Chronicle Queue

distributed unbounded persisted queue

## Hazelcast IMDG

distributed caching, in-memory data grid, message broadcast

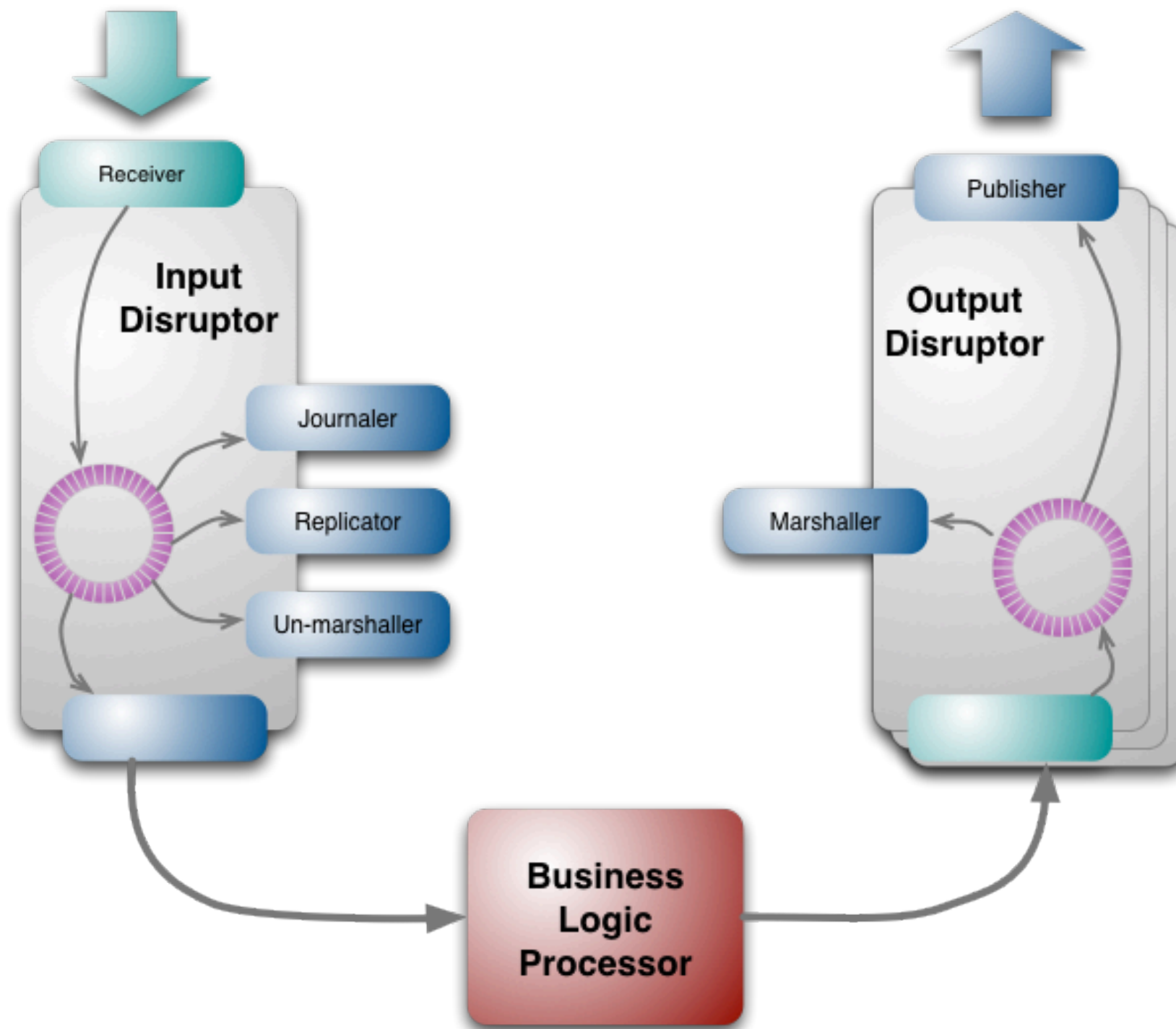
# Cost of locks

Method	Time (ms)
Single thread	300
Single thread with lock	10,000
Two threads with lock	224,000
Single thread with CAS	5,700
Two threads with CAS	30,000
Single thread with volatile write	4,700

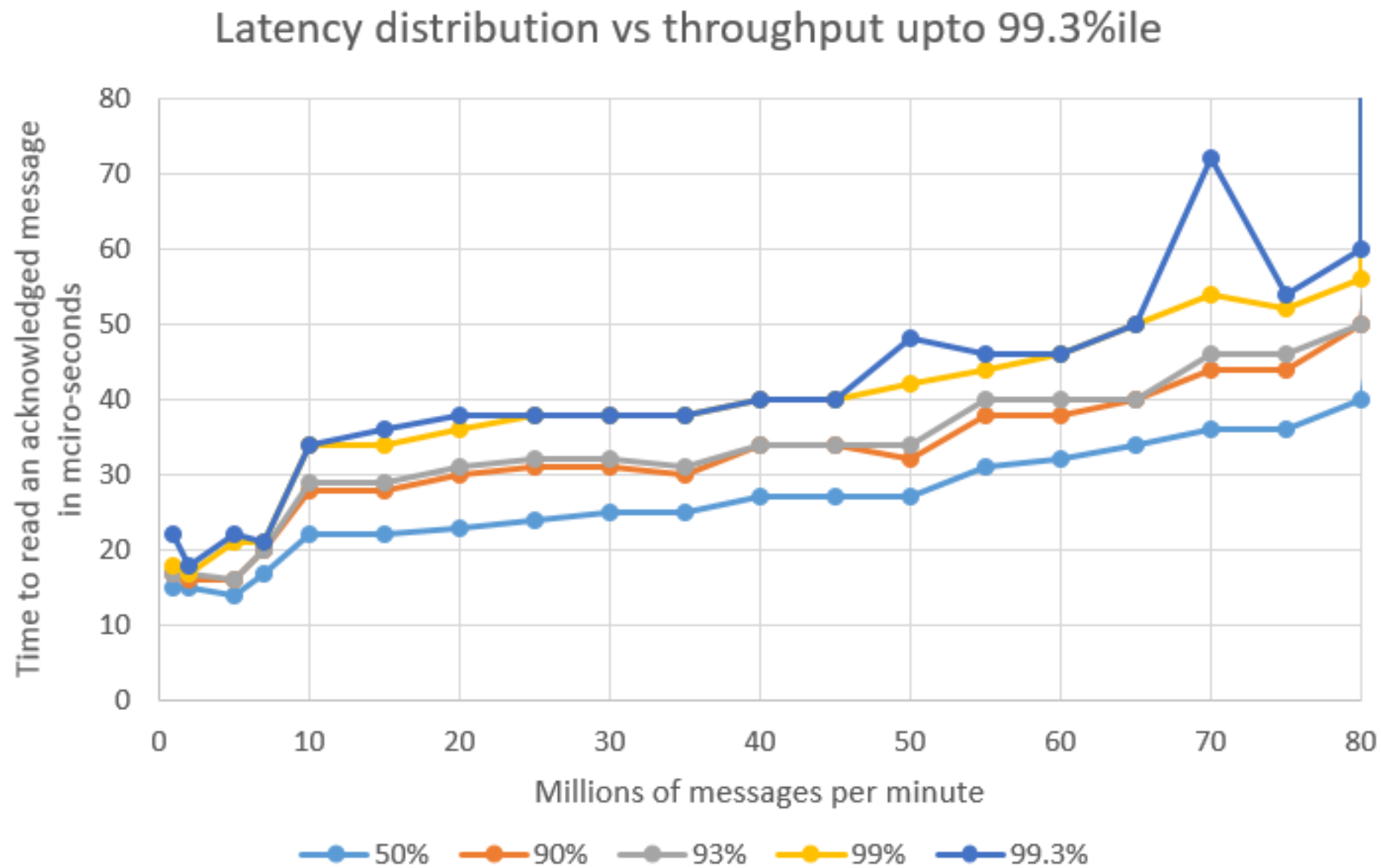
***Table 1 - Comparative costs of contention***

64 bit counter increment in a loop 500 million times; 2.4 Ghz CPU

# Disruptor Pattern Overview



# Chronicle Queue Performance



40 byte message replication and acknowledgment over TCP

# Score Data Representation

Semantic data models vs Graphical representation

Scalable Vector Graphics (SVG) vs Raster formats

MNX: Music Notation Markup Language Proposal

MNX-Generic:

graphical <-> semantic cross-reference



# ZScore Current State

A collection of third-party and newly-developed components

Score authoring: Adobe Illustrator + Javascript plugins

Proprietary network distribution and scheduling engine (Java)

Score rendering: INScore

# Score Authoring

**Bass Clarinet** P3

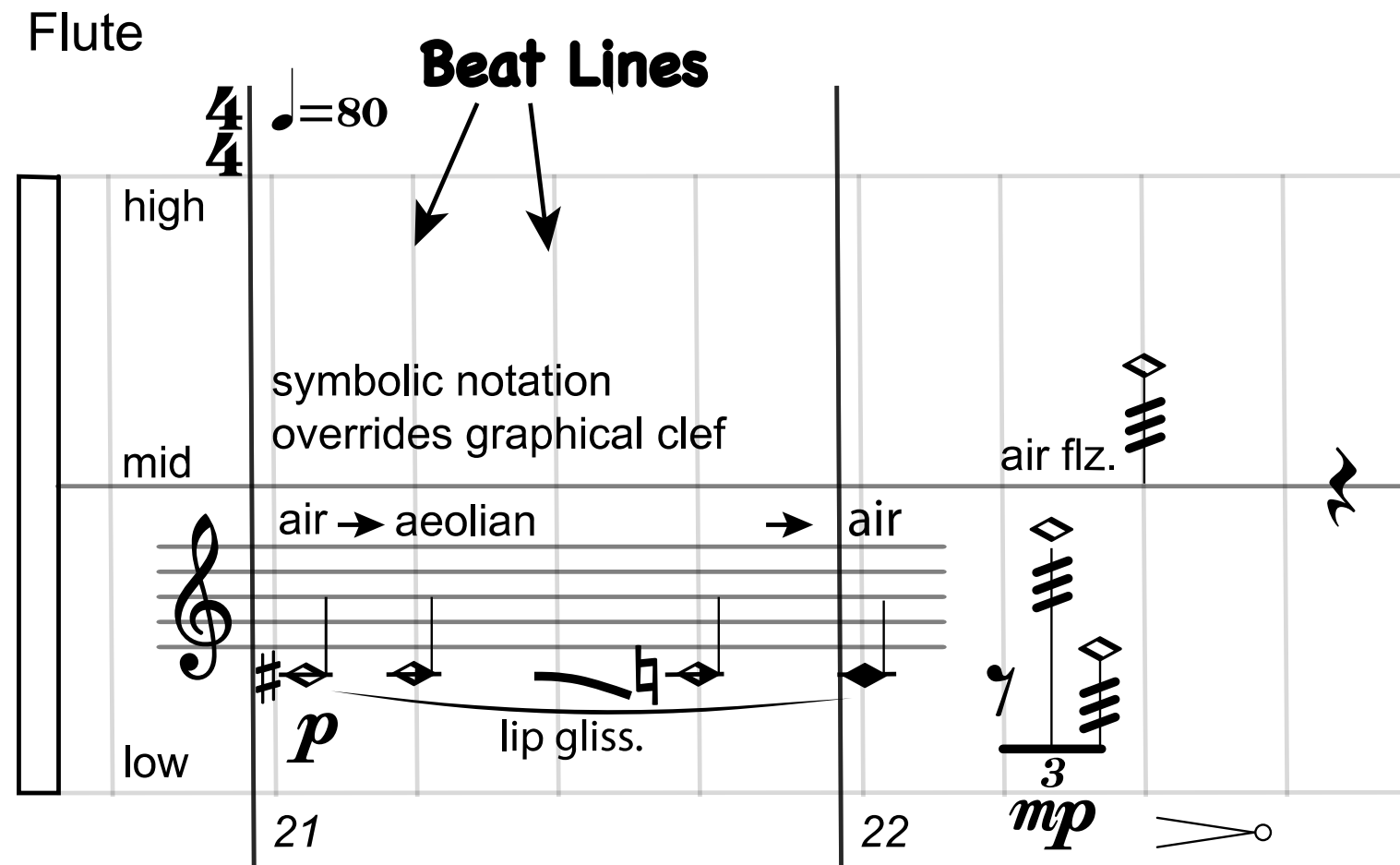
**Violin** P3

**Cello** P3

**AV** P1

Measure	13	14	15	16	17
Video	java:script:showContent('TL/scene/contentPanelMiddle', 'top', 0);	java:script:showContent('TL/scene/contentPanelMiddle', 'top', 0);	java:script:showContent('TL/scene/contentPanelMiddle', 'top', 0);	java:script:showContent('TL/scene/contentPanelMiddle', 'top', 0);	java:script:showContent('TL/scene/contentPanelMiddle', 'top', 0);
Audio	transition: 3600, 40, 255, 0, 1, TL/scene/contentPanelMiddle	transition: 3600, 40, 255, 0, 1, TL/scene/contentPanelMiddle	transition: 3600, 40, 255, 0, 1, TL/scene/contentPanelMiddle	transition: 3600, 40, 255, 0, 1, TL/scene/contentPanelMiddle	transition: 3600, 40, 255, 0, 1, TL/scene/contentPanelMiddle

# Time-space mapping and synchronisation

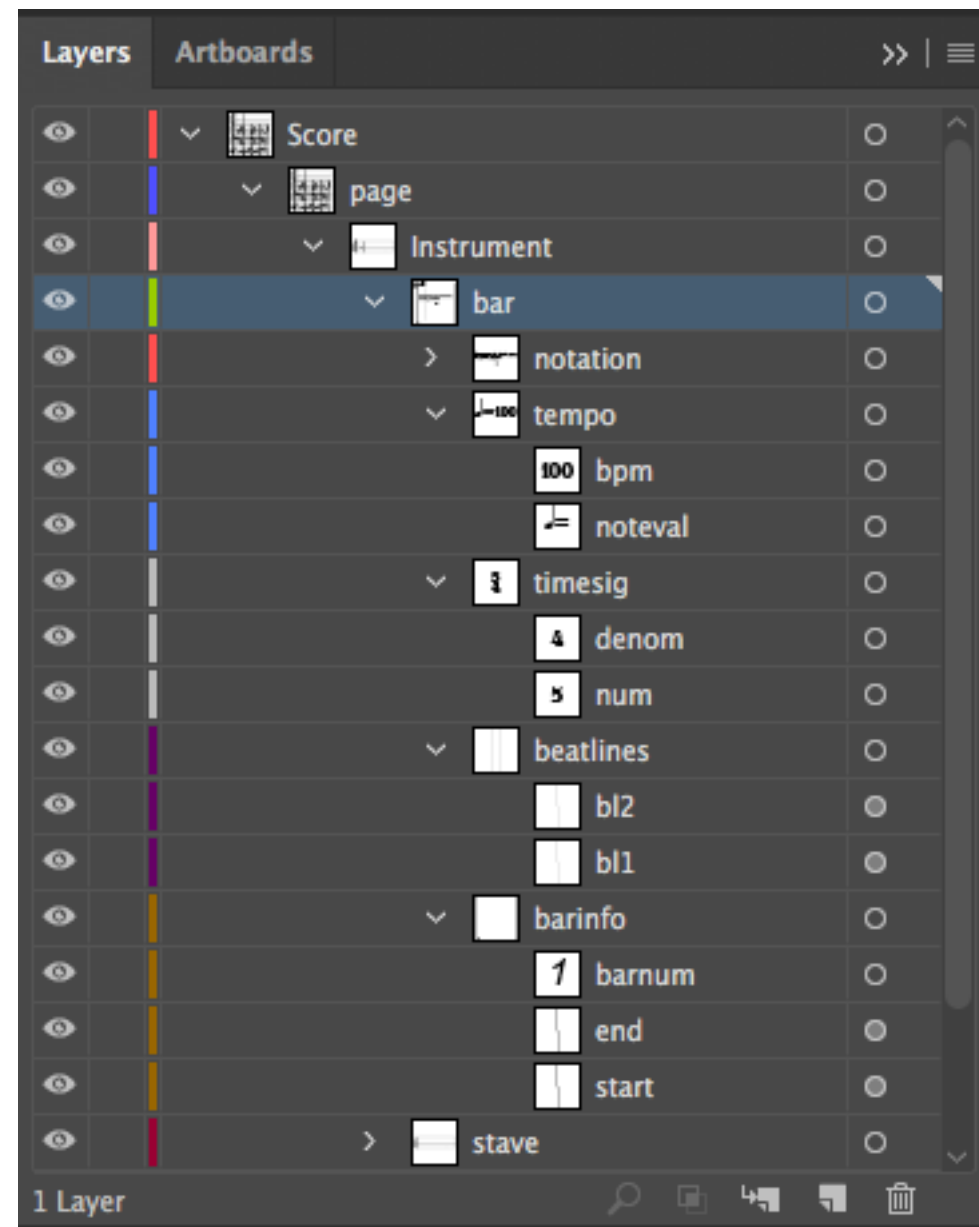


Beat Division Unit (BDU)

lowest event scheduling resolution, max 1/96

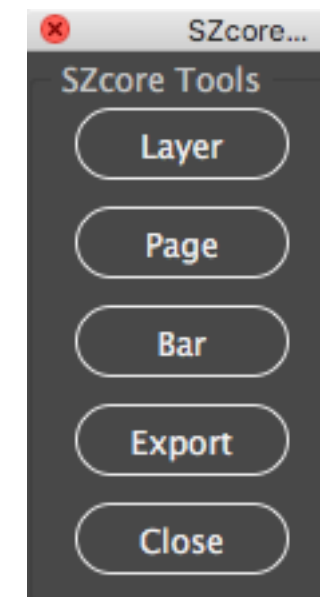
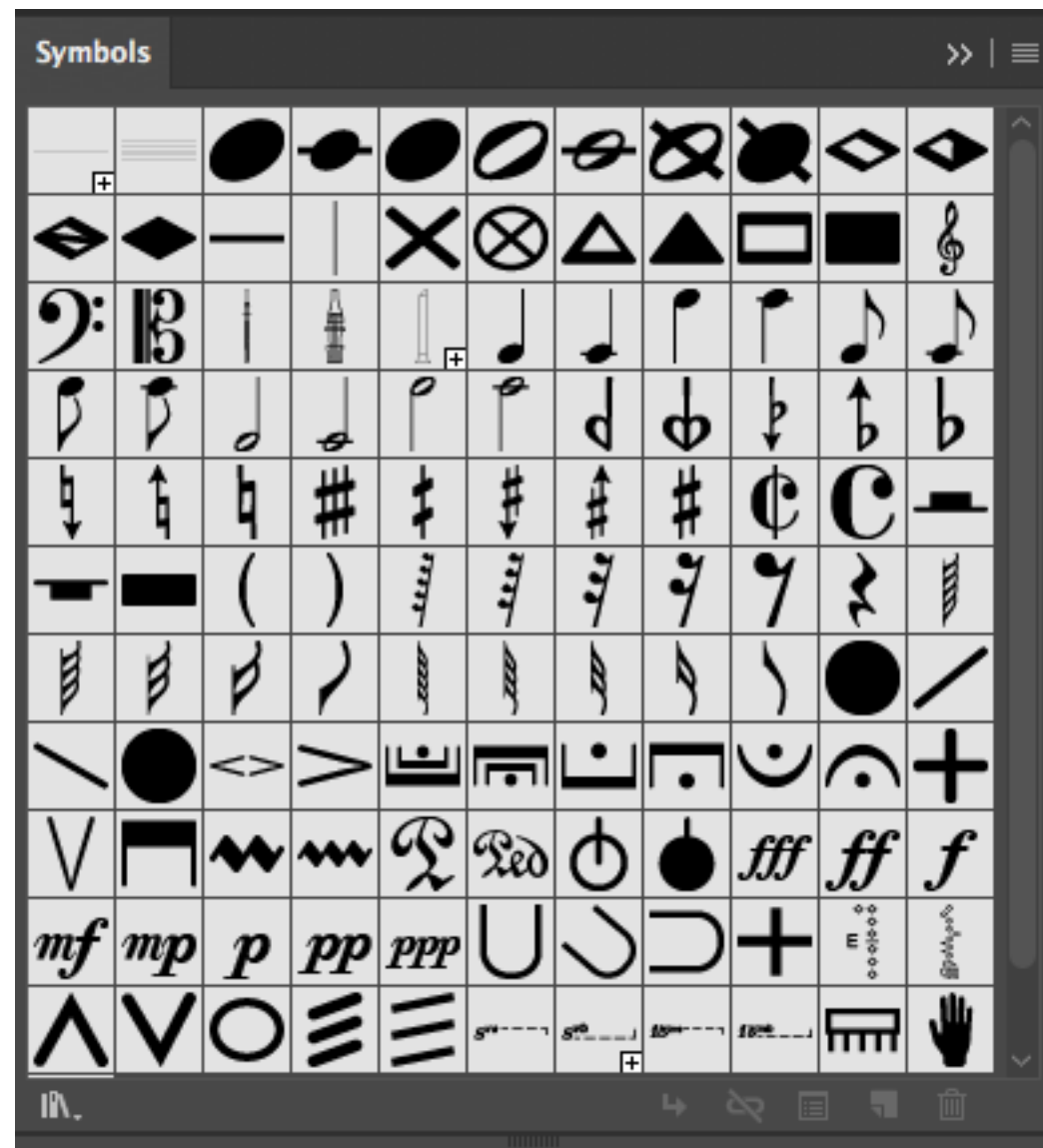
tempo-relative synchronisation message broadcast

# Musical context through layer hierarchy\*



\*Inspired by Rama Gottfried “SVG to OSC Transcoding...” TENOR 2015

# Symbol library and Javascript Plugins



# Distribution and Scheduling Engine

Score

Logger

**SZcore** Server Address: 192.168.0.4

Load Score

Playing: Ukodus

Parts:

Piano  
Cello  
Clarinet  
Flute  
FullScore

Send to Participants

Start Position: Page: 7 Bar: 26 Beat: 121

Play Control: 

Send Start Position

Play

Stop

Current Position: Page: 6 Bar: 25 Beat: 120 Tick: \_\_

Current Tempo: 80 Tempo Multiplier: 1.0

Participants

Send part choice to selected Participants: 

Send

Host	In port	Out port	Err port	Ping millis	Instrument
192.168.0.4	7000	7001	7002	4.5	Cello

# Score Part View

/ITL/scene

Ukodus


Cello

Connect

Server: 192.168.0.13

Cello

4/4



overpressure

IV pizz. arco

slow bow

mf

mp

white noise

free bowing change where necessary

msp

st

half pressure

III

IV

angled bowing

msp

ord.

harmonic gliss.

26

27


28

30

P7

Cello

4/4



circular bowing

harmonic gliss

IV

mf

mp

behind bridge pizz. IV

col legno batutto jeté

arco

msp

st

harmonic gliss

III

mp

33

34

35

P8

activeStave: /ITL/scene/stave

# ZScore Demo



# Future Work

Conductor gesture capture + modelling  
Wekinator integration

All User Interfaces in Internet Browsers  
MNX Integration

Interactive composition flow

Aeron middleware integration

# Questions ?

email    [slavko@zagorac.com](mailto:slavko@zagorac.com)

web      <http://www.zagorac.com>