CS 414 – Multimedia Systems Design

Lecture 34 – Synchronization (Part 2)

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Administrative

- MP4 posted
  - April 30 (preview for finalists) 5-7pm
  - May 1 grading for non-finalists 3:30-5pm and competition for finalists 5-7pm

Outline

- Synchronization Reference Models
- Synchronization in Distributed Environments
- Location of Synchronization
- Clock Synchronization

Reference Models

- We need reference models to
  - Understand various requirements for multimedia sync
  - Identify and structure run-time mechanisms to support execution of sync
  - Identify interface between run-time mechanisms
  - Compare system solutions for multimedia sync

Existing Models

- Little and Ghafoor
  - Sync multimedia objects are classified according to inter-media and intra-media sync, live and synthetic sync at levels:
    - **(a) Human level; (b) System level; (c) Physical level**
- Ehley, Furth, Ilyas
  - Sync multimedia objects are classified according to control jitter between media streams and with respect to distributed sync control:
    - **(a) using protocols, (b) using servers, (c) using nodes without server structure**

Synchronization Reference Model

- Sync model we will be evaluating in detail is according to Meyer, Effelsberg, Steinmetz:
  - Sync multimedia objects are classified according to
    - Media level
    - Stream level
    - Object level
    - Specification level

Media Level (1)

- Each application operates single continuous media streams composed of sequence of LDUs
- Assumption at this level: device independence
- Supported operations at this level:
  - *read(devicehandle, LDU)*
  - *write(devicehandle, LDU)*

Media Level (2) - Example

```
window = open(“videodevice”);
movie = open(“file”);
while (not EOF (movie) ) {
        read(movie, &LDU);
        if (LDU.time == 20)
                printf(“Subtitle 1”);
        else if (LDU.time == 26)
                printf(“Subtitle2”);
        write(window, LDU);  }
close(window);
close(movie);
```

Stream Level (1)

- Operates on continuous media streams and groups of streams
- Models inter-stream synchronization for need of parallel presentation
- Offers abstractions:
  - notion of streams,
  - timing parameters concerning QoS for intra-stream and inter-stream synchronization

Stream Level (2)

- Supports operations:
  - Start(stream), stop(stream), create-group(list-of-streams);
  - Start(group), stop(group);
  - Setcuepoint(stream/group, at, event);
- Classifies implementation according to
  - Support for distribution (end-to-end, local)
  - Support of type of guarantees (best effort, deterministic)
  - Support of types of supported streams (analog, digital)

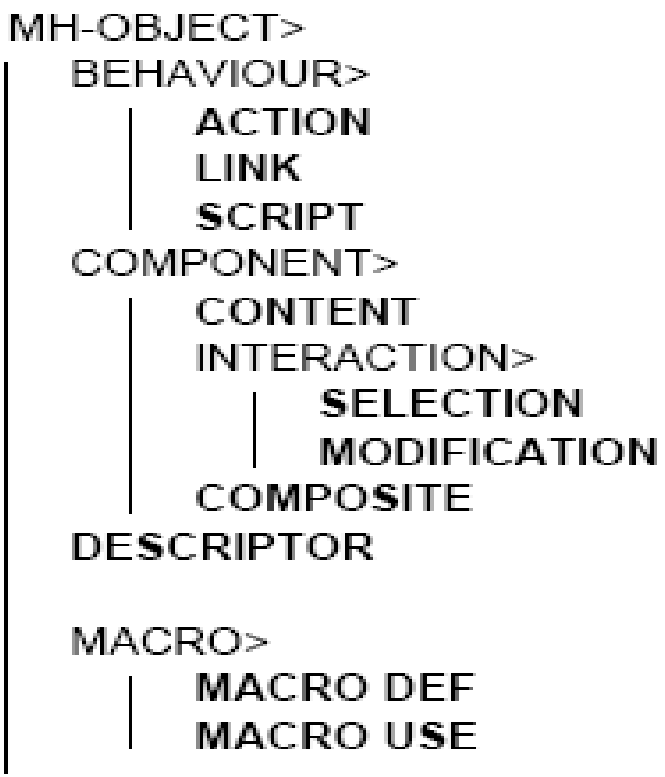
Object Level (1)

- Operates on all types of media and hides differences between discrete and continuous media
- Offers abstractions:
  - Complete sync presentation
- Computes and executes complete presentation schedules that include presentation of non-continuous media objects and calls to stream level
- Does not handle intra-stream and inter-stream synchronization
  - (relies on media and stream levels)

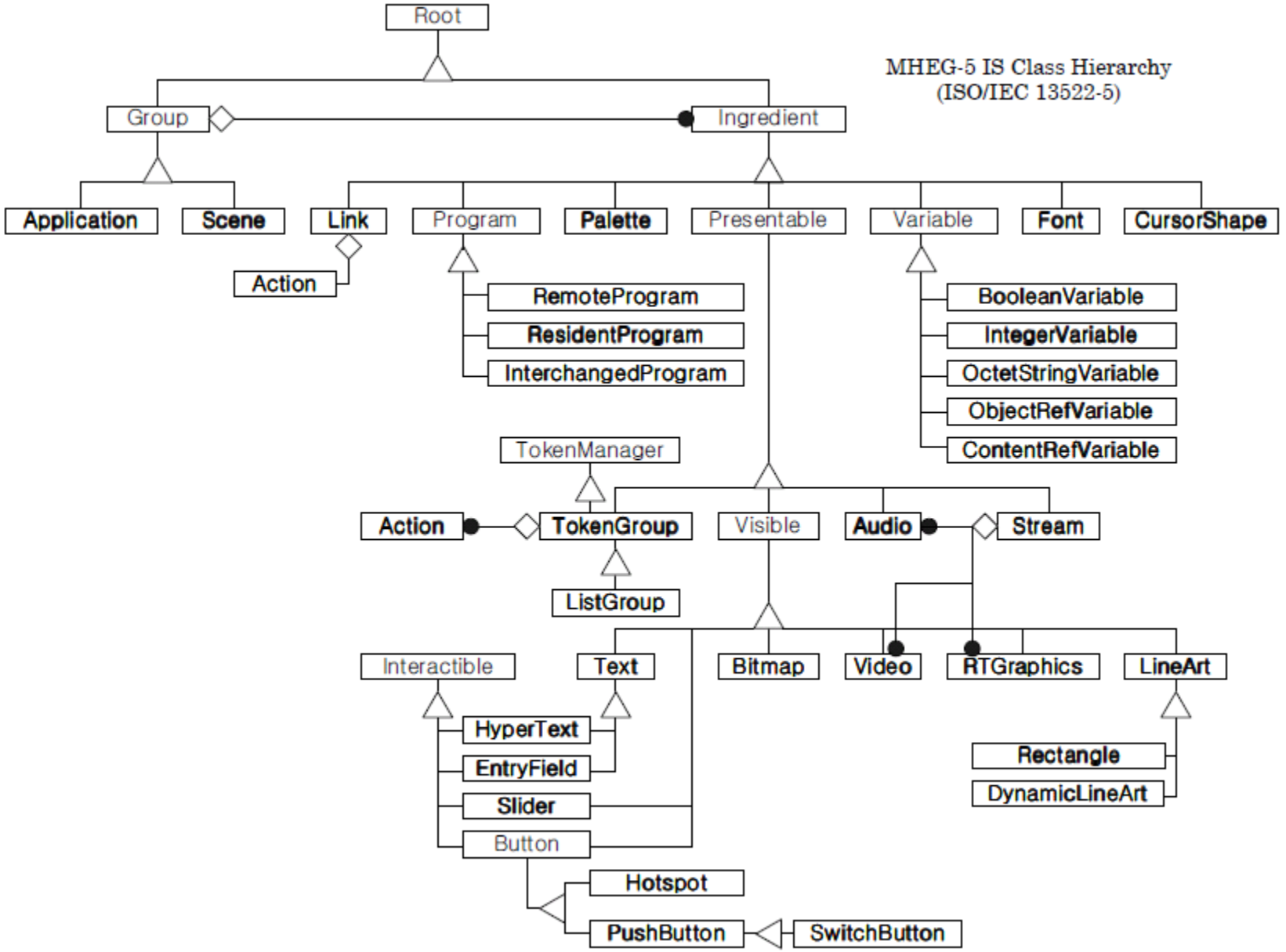
Object Level (2) - Example

- MHEG – Multimedia Hypermedia Experts Group of ISO
  - Defines representation and encoding of multimedia and hypermedia objects (object-based declarative programming language)
  - Provides abstractions suited to real-time presentations
    - implemented via multimedia synchronization functionalities
  - Provides abstracts for real-time exchange
    - implemented with minimal buffering
  - Evaluates status of objects and performs actions (e.g., prepare, run, stop, destroy)
    - For time-dependent streams – access to stream level
    - For time-independent streams – direct access the object to present it
- Classification of this level according to (a) distribution capabilities, (b) type of presentation schedule, (c) schedule calculation

MHEG Example (specified in SGML)



'>' means that this object has the following sub-classes.
Only the instances of the classes in bold
type may be interchanged.


MHEG-5 IS Class Hierarchy
(ISO/IEC 13522-5)
Root
Group
Ingredient
Application
Scene
Link
Program
Palette
Presentable
Variable
Font
CursorShape
Action
RemoteProgram
ResidentProgram
InterchangedProgram
BooleanVariable
IntegerVariable
OctetStringVariable
ObjectRefVariable
ContentRefVariable
TokenManager
Action
TokenGroup
Visible
Audio
Stream
ListGroup
Interactible
Text
Bitmap
Video
RTGraphics
LineArt
HyperText
EntryField
Slider
Button
Rectangle
DynamicLineArt
Hotspot
PushButton
SwitchButton

Specification Level

- Open layer included in tools which allow to create sync specifications
- Examples:
  - Synchronization editors, document editors, authoring systems, conversion tools
  - Examples of such tools: multimedia document formatter that produces MHEG specifications
- Classification:
  - Interval-based spec
  - Time-axes based spec
  - Control flow-based spec
  - Event-based spec

Synchronization in Distributed Environments

- Information of synchronization must be transmitted with audio and video streams, so that receiver(s) can synchronize streams
- Sync information can be delivered before start of presentation (used by synthetic synchronization)
  - Advantage: simple implementation
  - Disadvantage: presentation delay
- Sync information can be delivered using separate sync channel - out-band (used by live synchronization)
  - Advantage: no additional presentation delay
  - Disadvantage: additional channel needed

Sync in Distributed Environments

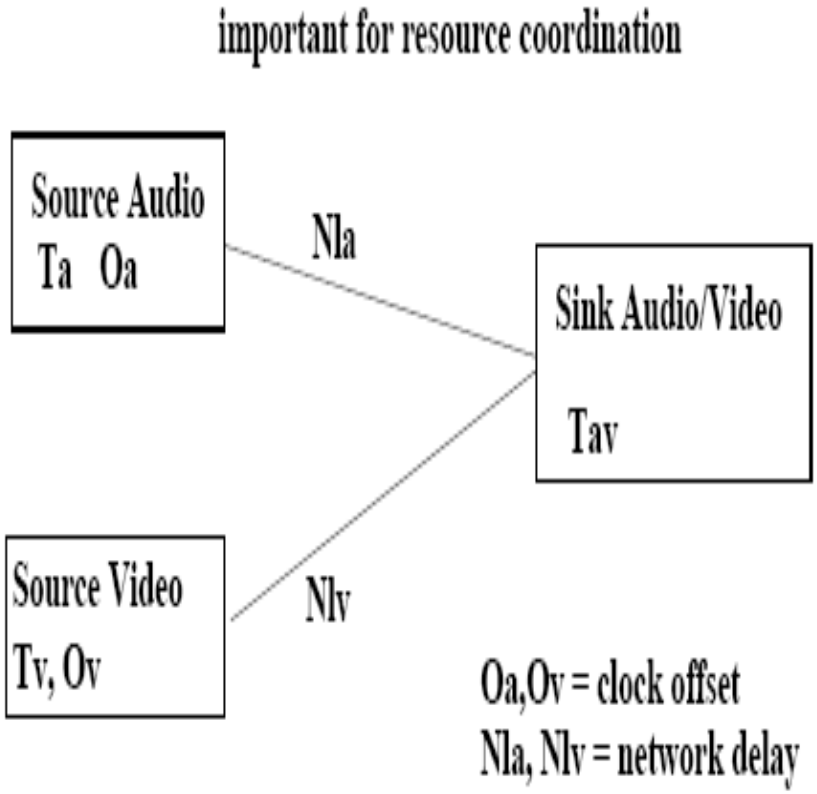
- Sync information can be delivered using multiplexed data streams - in-band sync
  - Advantage: related sync information is delivered together with media units
  - Disadvantage: difficult to use for multiple sources

Location of Sync Operation

- Sync media objects by combining objects into new media object
- Sync operation placed at sink
  - Demand on bandwidth is larger because additional sync operations must be transported
- Sync operation placed at source
  - Demand on bandwidth smaller because streams are multiplexed according to sync requirements

Clock Synchronization

- Sync accuracy depends on clocks at source and sink nodes
  - $T_a = T_{av} – Nl_a – O_a$
  - $T_v = T_{av} – Nl_v – O_v$
- End-to-end delay
  - $Nl_a = EED_a = T_{av}-T_a-O_a$
  - $Nl_v=EED_v = T_{av}-T_v-O_v$
  - $EED_a = (T_{a1}-T_{a2})/2$
- NTP (Network Time Protocol)

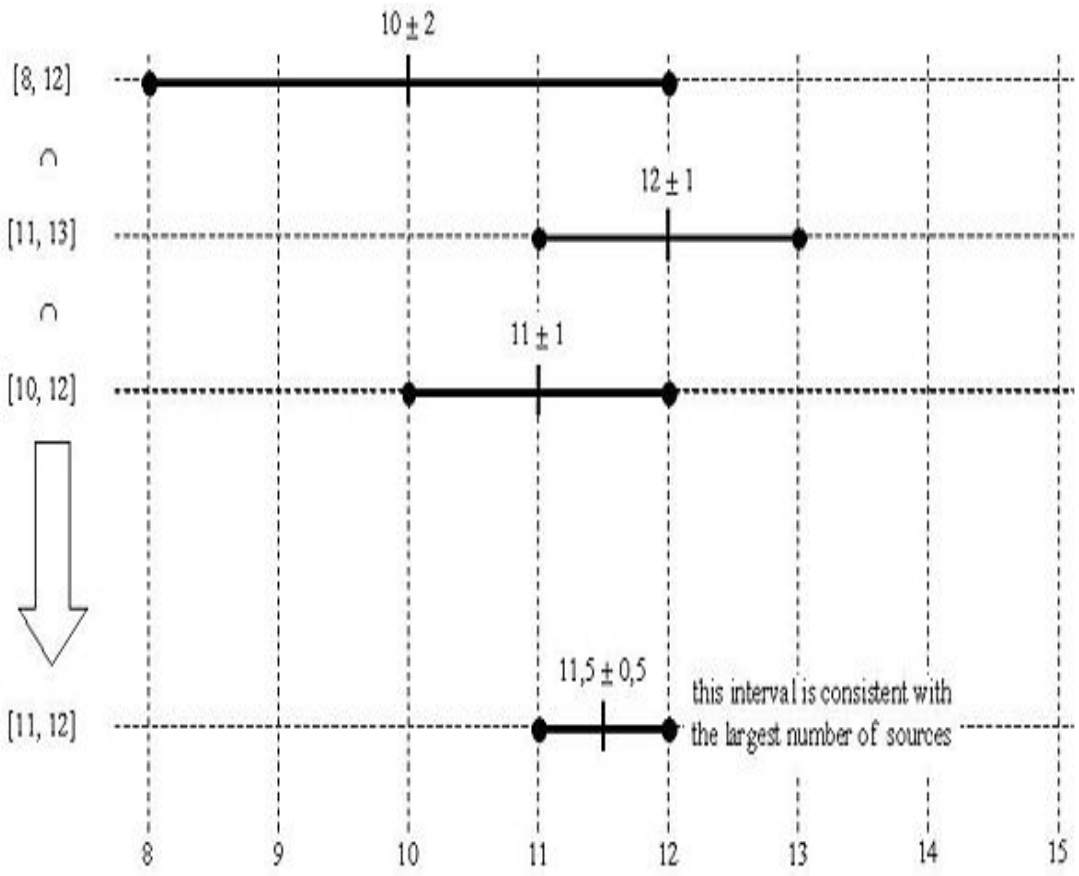


Network Time Protocol

- Protocol to sync clocks of computer systems over packet-switched, variable – latency data networks
  - Uses UDP port 123
  - Designed to resist effects of variable latency (jitter buffer)
  - Designed in 1985 by Dave Mills at U. Delaware
  - Can achieve accuracy of 200 µsec
  - Based on Marzullo Algorithm

Marzullo's algorithm (1984)
(intersection algorithm)

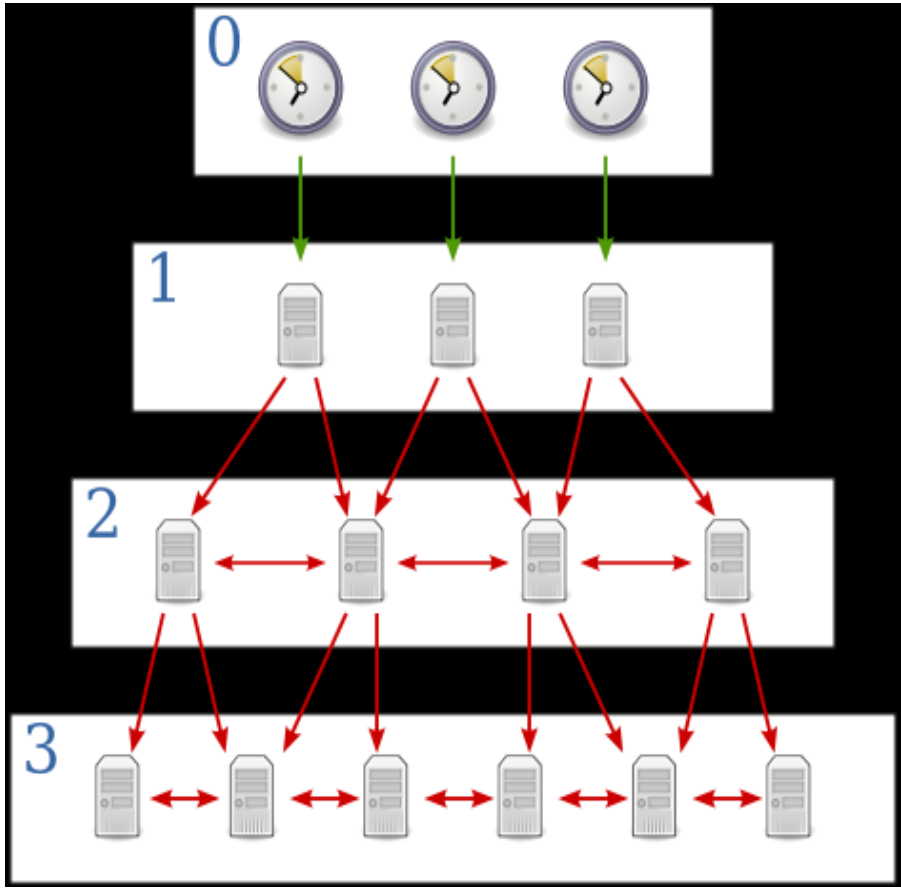
- Agreement protocol for estimating accurate time from a number of noisy time sources
- If we have estimates
- 10 ± 2, 12 ± 1, 11 ± 1, then interval intersection is 11.5 ± 0.5
- If some intervals don't intersect, consider intersection of majority of intervals



Source: wikipedia

Clock strata

- NTP uses hierarchical system of “clock strata”
- Stratum levels define distance from reference clock and exist to prevent cycles in hierarchy
  - Stratum 0
    - devices are atomic clocks, GPS clocks, radio clocks
  - Stratum1
    - computers attached to stratum0 devices
    - Act as servers for timing requests from Stratum 2 servers via NTP
  - Stratum2
    - (similar to Stratum1. but they also have peering relation to other stratum2 servers



Other Sync Issues

- Sync must be considered during object acquisition
- Sync must be considered during retrieval
  - Sync access to frames of stored video
- Sync must be considered during transport
  - If possible use isochronous protocols
- Sync must be considered at sink
  - Sync delivery to output devices
- Sync must consider support of functions such as pause, forward, rewind with different speeds, direct access, stop or repeat

Conclusion

Specification Layer - tools	Editing and Formatting Mapping of user-oriented QoS to abstractions at the object layer
Object Layer- Sync Spec.	Plan and Coordinate presentation Initiate presentation of time-dep. media by the stream layer Initiate presentation of time-indep. media Initiate presentation preparation actions
Stream Layer	Resource reservation and scheduling
Media Layer	File and device access